

**AC/DC
DIGITAL VOLTMETER
LM 1619**

WATER

SOLARTRON

TECHNICAL MANUAL

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LM1619 AC/DC DIGITAL VOLTMETER



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1970

SECTION 1

GENERAL

Introduction

The LM 1619 is a four window AC/DC Digital Voltmeter employing a charge transfer digitising technique. The D.C. measurement range of 0-1000 volts is covered in 5 ranges with a maximum sensitivity of 100 μ V and an accuracy of $\pm 0.1\%$ of reading $\pm 0.05\%$ of range. A built-in, mean reading, R.M.S. scaled AC/DC converter applied to the basic 2 volt range of the DC instrument provides AC measurement facility in four ranges covering 0-750V at an accuracy of $\pm 0.2\%$ of reading $\pm 0.1\%$ of range and a maximum sensitivity of 1mV.

The input terminals of the voltmeter are fully floating on both DC and AC ranges and to this end the AC/DC converter circuitry is powered by internal mercury cells. Polarity sensing and indication is automatic on D.C. ranges and the decimal point is positioned by the range selector. Binary coded decimal print out information, polarity and print command signals and external sample command facilities are available at the rear of the instrument. Range information is also available, and can be obtained at the rear panel by the addition of a B9A valve base with its associated wiring.

Specification

D.C. Voltage Measurements

Ranges:

No.	Range	Input Impedance	Sensitivity
1	0-199.9mV	> 1000M Ω	100 μ V
2	0-1.999V		1mV
3	0-19.99V	10M Ω	10mV
4	0-199.9V		100mV
5	0-1000V		1V

Manual range selection with automatic positioning of decimal point.

Polarity Indication: Polarity of input voltage is sensed and displayed automatically as a + or - sign.

NOTE: If successive readings are of opposite polarity the instrument requires two samples to indicate correct polarity and magnitude of input.

Accuracy: $\pm 0.1\%$ of reading $\pm 0.05\%$ [1 digit]. All ranges. Quoted accuracy is met after a 10 minute warm up time.

Input Current: $< 10^{-10}$ Amps. All ranges.

Calibration: Internal saturated standard cell provides calibration check to full accuracy over temperature range 15-40 $^{\circ}$ C.

Long Term Stability: Internal standard cell $< 0.05\%$ per year. All ranges $< \pm 0.1\%$ per year after calibration of basic range against internal standard cell [front panel pre-set control].

NOTE: All ranges may be reset to full accuracy using external standards [see Maintenance Section].

Overload Protection:

Ranges 1 and 2 350V continuous
 Ranges 3, 4 and 5 1000V continuous

Series Mode Rejection: A permanently connected filter provides > 40 dB attenuation of series mode interference at 45Hz increasingly at 12dB/octave at higher frequencies. The rejection is defined as

$$20 \log_{10} \frac{\text{input volts p-p}}{\text{error volts p-p}}$$

Filter Settling Time: 1 second to full accuracy for zero to full-scale step input.

Common Mode Rejection: Attenuation of Common Mode signals with 1000 Ω resistive unbalance in either input lead.

Ranges 1 and 2 80dB at DC and 50Hz
 Ranges 3 and 4 40dB at DC and 50Hz
 Range 5 20dB at DC and 50Hz

NOTE: A.C. common mode defined as for series mode:

$$20 \log_{10} \frac{\text{input volts p-p}}{\text{error volts p-p}}$$

Maximum Common Mode Signal: ± 250 V D.C. or peak AC with respect to chassis [earth].

A.C. Voltage Measurements

Ranges:

No.	Range	Input Impedance	Sensitivity
1	0-1.999V	10M Ω /50pF	1mV
2	0-19.99V		10mV
3	0-199.9V	1M Ω /50pF	100mV
4	0-750V		1V

Manual range selection with automatic positioning of decimal point.

Polarity Indication: The polarity indicators are blanked on AC ranges.

Accuracy: $\pm 0.2\%$ of reading $\pm 0.1\%$ of range [2 digits]. 40Hz to 10KHz on all ranges. Quoted accuracy is met after a 10 minute warm up time.

Settling Time: <3 seconds to full accuracy for zero to full scale step input.

Long Term Stability: AC converter and 2V range <0.05% per year. Attenuated ranges <0.1% per year. [After calibration of DC section of instrument against internal standard cell]. All ranges resettable to full accuracy using external standards. [see Maintenance Section].

Overload Protection:

Range 1 150V R,M,S. continuous [300V for up to 5 seconds].

Range 2, 3 & 4 750V R,M,S. continuous.

Common Mode Rejection: Attenuation of common mode signals with 1000 Ω resistive unbalance in either input lead.

Ranges 1 and 2	60dB at DC and 50Hz
Range 3	40dB at DC and 50Hz
Range 4	20dB at DC and 50Hz

NOTE: The rejection is measured as in the D.C. Specification.

Maximum Common mode signal: ± 250 V D.C. or peak A.C. with respect to chassis [earth].

Battery Life: >800 hours continuous operation. A switch position is provided to check battery voltage before use. Full converter accuracy is maintained down to 80% of nominal battery voltage. The battery supply is automatically switched off during D.C. measurements or when the mains supply is disconnected.

General [overall instrument]

Maximum Reading: 1999.

Operating Modes:

AUTO 1,1-2,3 readings per second.
MANUAL Reading held
SAMPLE In the MANUAL condition a "single shot" may be initiated by a) front panel push button; or b) remotely by contact closure or 6 volt negative going pulse of rise time <50 μ S.

Zero Stability: No zero adjustment is necessary over the operating temperature range of the instrument.

Operating Temperature Range: 0 $^{\circ}$ to +50 $^{\circ}$ C.

Temperature Coefficients: Internal standard cell <0.0045% per $^{\circ}$ C. All ranges <0.02% per $^{\circ}$ C. The instrument may re-set to full accuracy at a given temperature [15 $^{\circ}$ C-40 $^{\circ}$ C] using internal standard cell.

Input Isolation: The two-terminal fully isolated and guarded input may be floated up to ± 250 volts D.C. or peak A.C. with respect to chassis [earth]. Isolation impedance signal Lo to chassis 200M Ω in parallel with <1000pF. Input Lo may be linked to front panel chassis terminal. Input Hi and Lo terminals are completely isolated from printer output.

Power Input: 115/230 volts AC $\pm 15\%$, 44Hz to 440Hz, 25VA.

Dimensions: Housed in bench case: 8 $\frac{1}{2}$ " [21.6cm] wide; 4 $\frac{1}{4}$ " [11cm] high; 16" [41cm] deep.

For rack mounting: 8 $\frac{1}{2}$ " [21.6cm] wide; 3 $\frac{1}{2}$ " [8.9cm] high; 15" [38cm] deep [from front panel face].

Weight: 11 lbs [5Kg].

Accessories: Supplied with instrument.

- 1 - input lead
- 2 - alligator clips
- 2 - test prod connectors
- 1 - input terminal link
- 1 - handbook.

Print out Information

Binary coded decimal [1248 code] plus polarity and print command outputs available from a multi-way connector at the rear of the instrument.

Logic Levels:-

	ON	OFF
	["1" State]	["0" State]
BCD and Polarity	- 5v to - 12v	0V to -1V
Maximum current	± 1 mA in either state.	
Print Command:	Change of voltage level from 0V to -6V from 1k Ω source.	

Print Out:

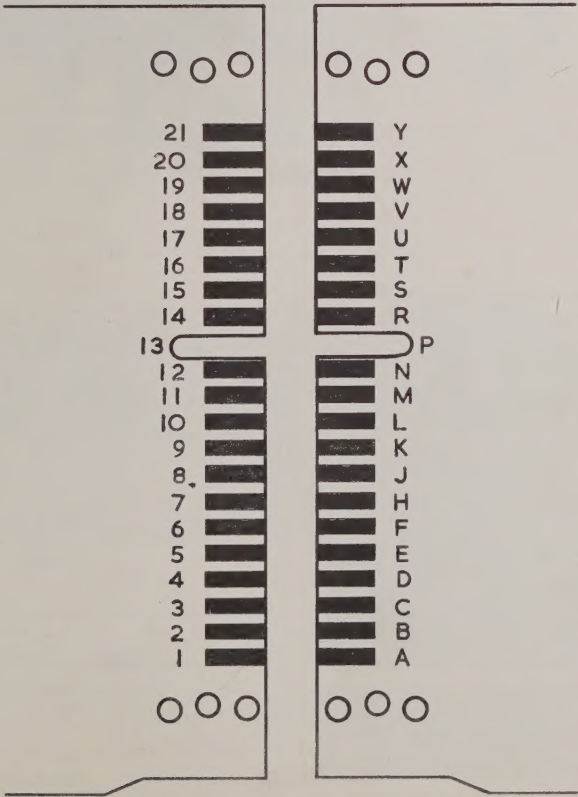
Pin No	Function
1	4 $\frac{1}{2}$ *
2	4 $\frac{1}{2}$
3	8 $\frac{1}{2}$ *
4	8 $\frac{1}{2}$
5	Internal Connection

Print Out: [continued]

Pin No	Function	Pin No	Function
6	Polarity -ve	F	1 ₂
7	Polarity +ve	H	2 ₂ *
8	Sample Command	J	2 ₂
9	Print Command	K	4 ₂ *
10	Display Blanking	L	4 ₂
11	100kHz clock pulses	M	8 ₂ *
12	Reset line	N	8 ₂
13	No connection	P	No connection
14	Internal Connection	R	1 ₃ *
15	-12V rail [max. load 10ma nom.]	S	1 ₃
16	Common rail	T	2 ₃ *
17	+12V rail [max. load 5ma nom.]	U	2 ₃
18	+70V rail [zero current availability]	V	4 ₃ *
19	+250V rail [max. load 5ma nom.]	W	4 ₃
20	Internal Connection	X	8 ₃ *
21	1 ₄	Y	8 ₃
A	1 ₁ *		
B	1 ₁		
C	2 ₁ *		
D	2 ₁		
E	1 ₂ *		

NOTE: There is a 1kΩ resistor in series with all binary outputs except those marked with an asterisk [*].

Optional Extra: Multi-way print out connector
[Type EX 1866].



SECTION 2 OPERATION

Installation

1. The instrument is wired ready for connection to a 184 - 265 volts mains supply. If 92 - 132 volt working is required the procedure described below should be followed:-

a] Remove 4 screws from two plastic retainers on the instrument rear panel. Slide the top cover backwards and place aside.

b] Alter the linking to the new format as shown in fig. 2.3. Link location is shown in fig. 2.2.

c] Replace the top cover by reversing the above procedure.

2. Check presence, continuity, and rating of the mains fuse. The value should be 150mA SLO, BLO for 184 - 265 volt operation and 300mA SLO, BLO for 92 - 132 volt operation.

3. Wire the mains lead to an appropriate mains plug, connecting:- red to LINE [L]; black to NEUTRAL [N]; green to EARTH [E].

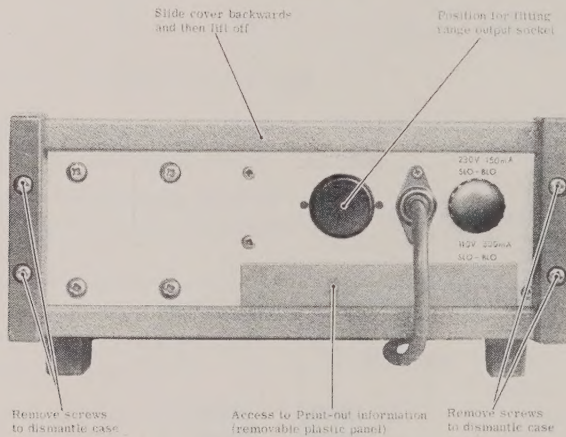


Fig. 2.1 Case Removal.

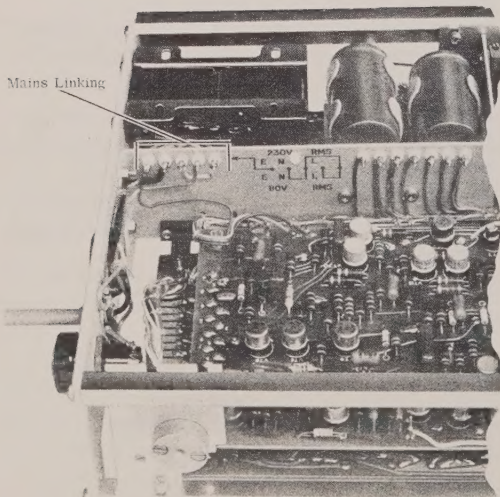


Fig. 2.2. Mains Link Location

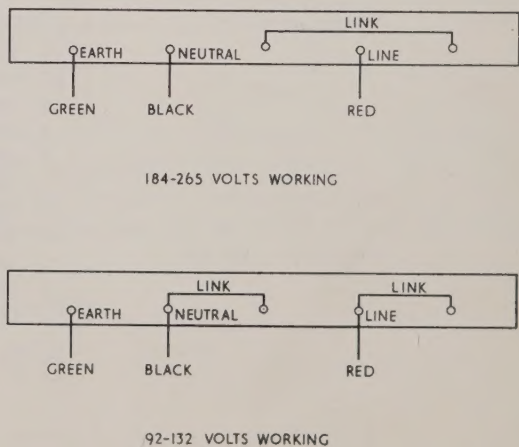


Fig. 2.3 Mains Linking.

Controls

1. RANGE Switch: An eleven position rotary switch giving a choice of 5 D.C. input ranges, 200mV, 2V, 20V, 200V and 1000V full scale, plus an internal calibrator position and 4 A.C. ranges, 2V, 20V, 200V and 750V full scale, plus a battery check position.

2. CAL Control: A preset screwdriver adjusted control enabling the instrument to be calibrated against its internal standard cell.

3. AUTO/MANUAL Switch: A two position slider switch giving the choice of two sampling modes:-

- a] continuous sampling at a repetition rate of approximately two samples/second.
- b] single shot operation initiated by the SAMPLE button.

4. SAMPLE button: This push button is used in conjunction with the AUTO/MANUAL switch. The button should not be pressed with the AUTO position selected as this may cause an erroneous reading. When the MANUAL position is selected the button will initiate one cycle of operation. If the voltage applied to the input is of opposite polarity to that displayed by the instrument before sampling, the button will require pushing twice in order to obtain the correct reading. In this case the first reading obtained will be 0000.

5. Input Terminals: Three screw terminals, each drilled to accept a 4mm plug. The HI and LO terminals are fully isolated with guarded input. The third terminal is a CHASSIS connection.

6. Link: For normal measurements the link is connected between terminals LO and CHASSIS.

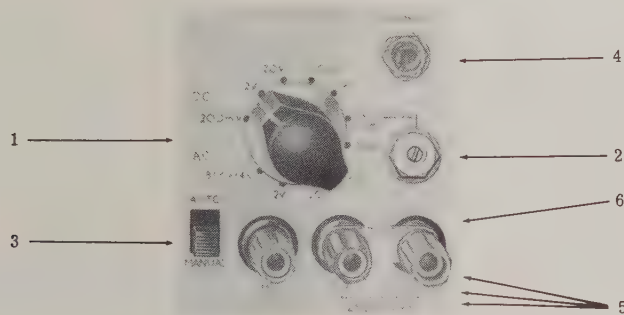


Fig. 2.4 Controls and Connectors.

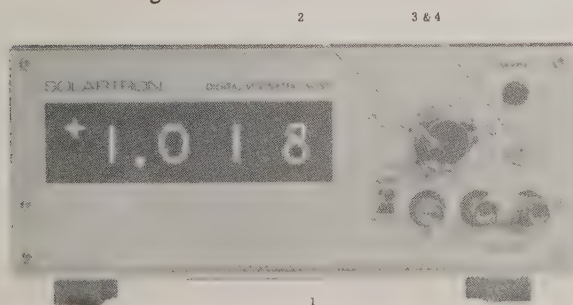


Fig. 2.5 Calibration.

Calibration

The following calibration procedure should be performed before taking a measurement which requires a high degree of accuracy. A 10 minute warm-up period should preferably be allowed before starting the calibration procedure.

1] Set the AUTO/MANUAL selector to AUTO.

2] Set RANGE switch to the CAL position.

3] Using a screwdriver adjust the CAL control for a display reading of +1.018.

4] Adjust the CAL control so that the units digit just changes to "9" i.e. the reading alternates between displays of +1.018 and +1.019. This corresponds to a reading of +1.0185.

Battery Check

Prior to making AC measurements the voltage of the internal battery supply for the AC/DC converter should be checked.

1] Set the AUTO/MANUAL selector to AUTO.

2] Set RANGE switch to the CHECK BTY. position.

A reading in excess of 14 volts should be displayed. A reading below this figure indicates that the mercury cells, located inside the attenuator screening box, are in need of replacement.

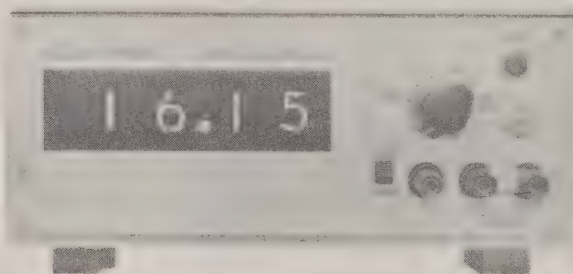


Fig. 2.6 Battery Check.

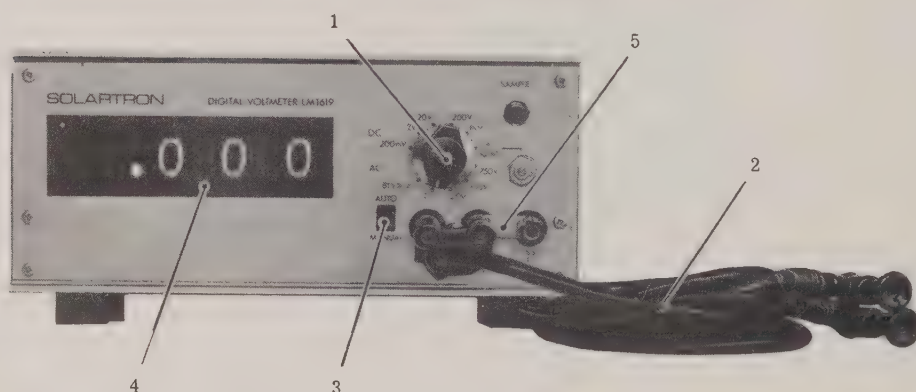


Fig. 2.7 Voltage Measurement

Voltage Measurement

CAUTION

The maximum voltages that can safely be applied to the instrument are:-

D.C. Ranges:

200mV and 2V	<u>+350V</u>
20V, 200V and 1KV	<u>+1000V</u>

A.C. Ranges:

2V	150V RMS [up to 300V for 5secs]
20V, 200V and 750V	750V RMS.

With the link removed, the maximum common mode signal that may be applied between signal Lo and the CHASSIS [earth] terminal is +250V D.C. or peak AC.

1] Set range selector to the appropriate AC or DC range. If the approximate value of the input voltage is not known set the range selector to the least sensitive range.

2] Connect signal lead to the source of voltage to be measured, connecting the red terminal to signal high and the black terminal to signal low.

3] Set the mode selector to AUTO or MANUAL as required.

4] Read voltage from display, if necessary down-ranging to obtain greater resolution.

5] For normal measurements, where floating input is not required, the link should remain connected between terminals LO and CHASSIS.

NOTE

If a reading of 1999 is obtained the instrument should be up-ranged. A display of 1999 is an overload condition, the counter being staticised and not re-circulated in the normal manner.

SECTION 3

TECHNICAL DESCRIPTION

Basic Operational Principle

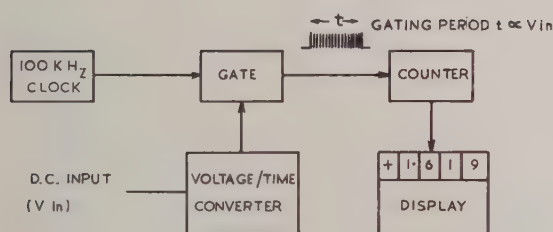


Fig. 3.1 Voltage/Time Converter

The LM 1619 Digital Voltmeter employs a digitisation technique whereby the gating period of a clock oscillator is varied, by means of a voltage-to-time converter, in direct proportion to the magnitude of the signal under measurement. The number of clock pulses passed during the gating period are totalised in a display counter. The voltage-to-time converter is so calibrated that the total number of clock pulses, at the chosen frequency of 100kHz, gated to the counter and numerical display produce a direct reading of the magnitude of the input signal.

Voltage-to-time Converter

A simplified block diagram of the voltmeter is given in fig. 3.2 and the operational waveforms are shown in fig. 3.3.

Input Circuit: The signal to be measured is applied across terminals HI and LOW. The HI terminal is the signal path and the LO terminal is floating internally but may be connected to earth externally. The range switch provides five D.C. ranges, two of which are direct inputs of 200mV and 2V full scale. The remaining three are attenuated ranges of 20V, 200V and 1000V full scale. The sixth position of the range switch applies the internal saturated reference cell to the basic 2V DC range of the instrument, thus providing a calibrating facility. Highly stable, precision metal film resistors are used to make up the attenuator such that the accuracy of the attenuated ranges is fully commensurate with that of the basic DC instrument. The 200mV range is obtained by defining amplifier reference current such that the

basic sensitivity of the instrument is increased by a factor of ten. This enables the use of a simple two stage attenuator on D.C. ranges and also gives the added advantage of extremely high input impedance on the two most sensitive ranges.

Four A.C. ranges are provided with a basic sensitivity of 2V multiplied by a three-stage frequency compensated attenuator. The attenuation factor on the 750V range provides a theoretical full scale maximum of 2000V but is specified at 750V due to other considerations, such as switch contact breakdown limitations. This statement is also true for the 1000V D.C. range, for the same reasons.

The last position of the range switch provides a battery check position by applying the nominal 16V AC/DC converter battery supply rail to the 20V range of the DC instrument. Although the converter will operate satisfactorily with battery voltages down to 80% of nominal it is recommended that the batteries should be replaced when a reading below 14V is displayed in the battery check position. This is because the mercury cells used maintain their E.M.F. almost until the point of breakdown. This point is indicated by a reading of less than 14V.

The AC/DC converter is fundamentally a mean-reading device but it is scaled by the form-factor for a sine-wave such that the output is the D.C. equivalent of the R.M.S. of the input. The output from the converter is 2V full-scale on all ranges and is applied to the basic 2V range of the D.C. instrument.

The input signal, suitably attenuated or, for AC ranges, attenuated and converted to D.C., passes via a permanently connected filter and the reed relay choppers to the amplifier input. The amplifier is designed to operate on a negative input and thus relays A and B are arranged as a changeover switch and driven by polarity sensing circuitry such that a negative input is applied to the amplifier whatever the polarity of signal applied to the input terminals. To maintain the input terminals fully floating, with consequent rejection of common mode signals, the contacts of relay E open as the contacts of the changeover relay [A or B] close. The action is break before make, which ensures complete isolation, and the input signal is stored on capacitor Ca.

Description of Operation: The following description assumes a negative signal applied to the input terminals. A polarity change will be separately described at the end of the section.

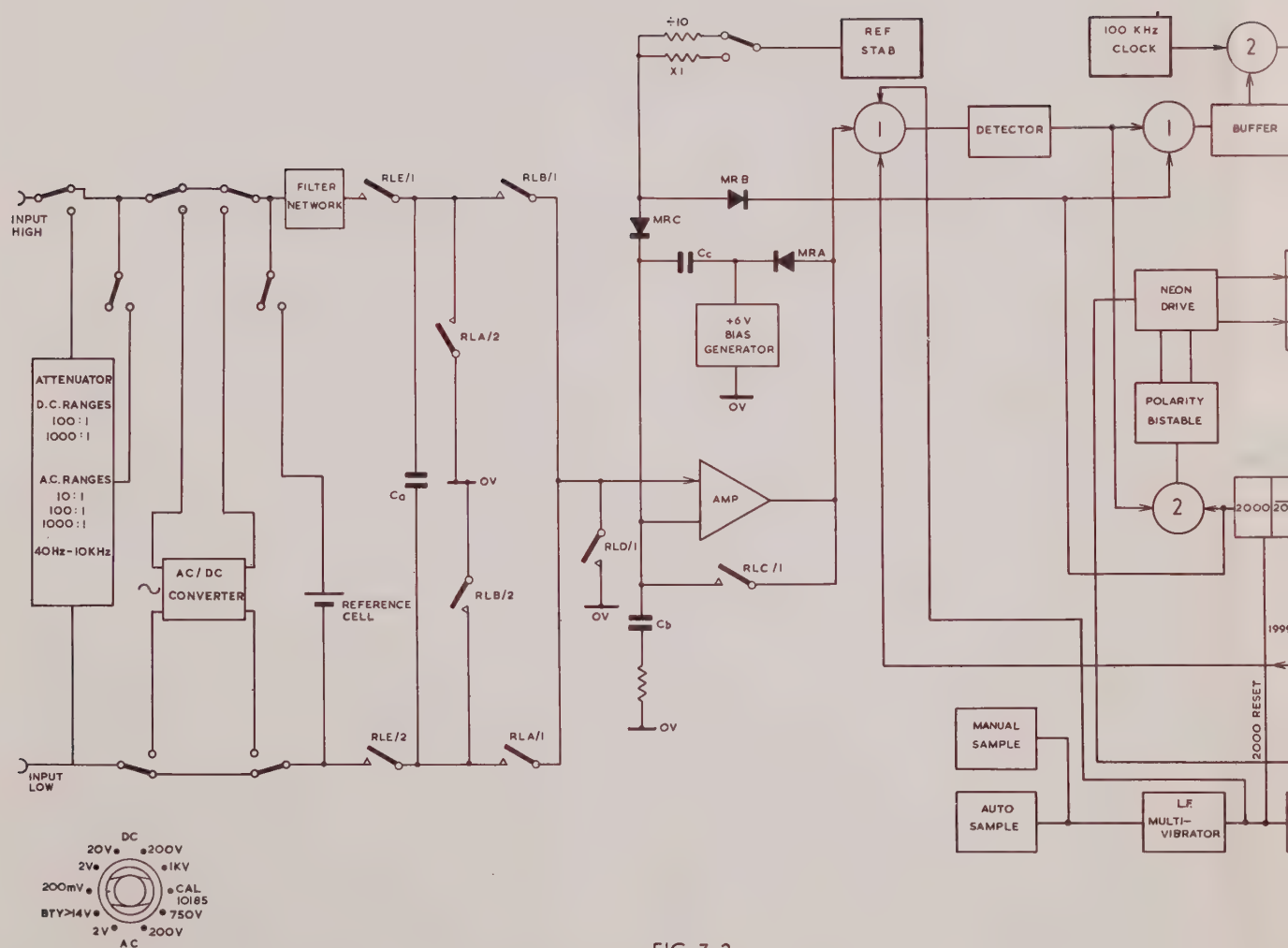
Input sampling is initiated by a multivibrator which on AUTO mode produces negative pulses 20 milliseconds in duration at a repetition frequency of approximately 2Hz to give two samples/sec. With the mode switch set to MANUAL a holdoff is applied to the multivibrator and a single pulse is produced following operation of the panel mounted SAMPLE button. This provides a single-shot facility. At time A [fig. 3.3] the negative edge from the multivibrator operates relay C, closing the loop between amplifier output and differential input. Relays E, D and B then operate such that the negative signal stored on Ca is applied to the amplifier input previously held at 0V by the contact of relay D. Since relay C is closed the differential input is taken to a level compounded by the sum of the input signal and the amplifier offset voltage. Diode MRA is reverse biased by virtue of the negative level at the amplifier output and the approximate bias level of +6V at its cathode and thus capacitor Cc is effectively in parallel with capacitor Cb. These capacitors now charge to the input signal plus offset during the remainder of the 20 millisecond pulse period.

At time B [fig. 3.3] the positive edge from the multivibrator resets the 2000 bistable to the 2000 state which applies a forward bias to diode MRB which in turn applies reverse bias to MRC. This removes the reference current supply, derived from a highly stable voltage reference source and a precision metal film current definition resistor. The contact of relay C opens and relay D contact closes to 0V. Since relay C is open and MRA is reverse biased the amplifier is now operating at high gain in an open-loop condition with the input closed to 0V and the differential input at a negative potential. The output will therefore swing rapidly positive until diode MRA conducts, making the amplifier configuration a closed-loop with capacitive feedback. The final output voltage will now be the product of the input voltage and the capacitance ratio of Cb to Cc plus the initial charge on Cc, and is a linear function of the input signal. The amplifier differential input returns to the original offset level and the charge transfer from Cb to Cc is completed during a 10 millisecond settling period obtained by gating the clock oscillator with the 2000 bistable output. The return of this bistable to the 2000 state is inhibited by an output from relay D driver during the period that relay D contact is open. A small delay is included so that at the time that relay D contact closes and the counter reset pulse is generated the 2000 bistable remains inhibited. Thus the counter registers 3000. The count continues for a further 1000 pulses to enable the charge transfer to complete, as

previously described, and the counter registers zero [4000]. The forward bias on diode MRB derived from the 2000 bistable is thus removed and reference current applied to the differential input via diode MRC. Capacitor Cc now discharges at a rate determined by the reference current source and the amplifier produces a linear output ramp-down until MRA ceases to conduct. The amplifier, operating once more in the open-loop configuration, produces a rapid transition through zero causing the detector to give an output which closes the clock gate and operates the display unblanking circuitry. The various factors described effecting the conversion of the D.C. input signal to the time period of the output ramp are constants and therefore it can be stated that the ramp-down period is directly proportional to the input signal. By stopping the counter with the detector output at the end of the ramp-down a direct reading of the magnitude of the input signal is displayed on operation of the display unblanking.

1999 Gate: With an input signal in excess of full-scale on the range in use a count of 1999 will be reached before ramp-down is complete. In this condition the seven input AND gate produces an output which is fed to the detector and thus the clock gate is closed. 1999 will be continually digitised until the voltmeter is up-ranged.

Polarity Change: When the input signal changes sign an initial positive potential will be applied to the amplifier input causing the output to swing negative. The detector will produce an output and thus the gate between the 2000 bistable and the polarity bistable is opened at the instant when reference current is switched [when the 2000 bistable changes state] and the polarity bistable is thereby triggered. The polarity bistable outputs feed the drive circuitry to illuminate the appropriate neon polarity indicator and this circuit is also used to steer the relay A and B driver such that the necessary changeover takes place to ensure a negative input to the amplifier on the succeeding sample. For the duration of a polarity reversal routine the display registers zero. When the instrument is switched to AC ranges, the polarity neons are blanked. The polarity sensing circuitry is, however, still operative since although the polarity of output from the AC/DC converter is known, a polarity change may still be required following changeover from D.C. to A.C. ranges.



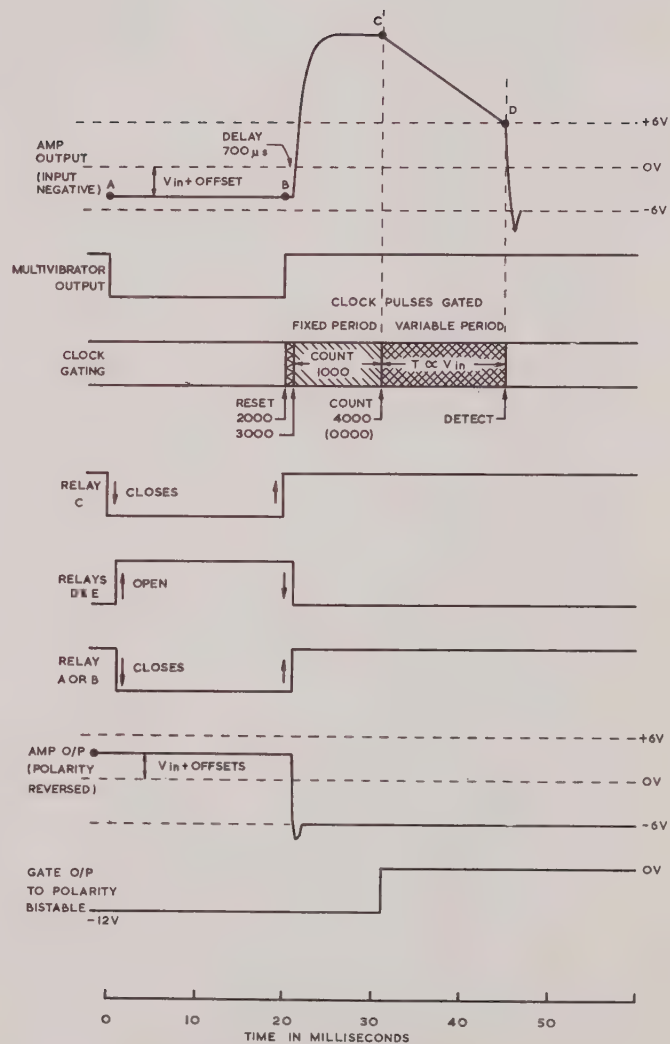
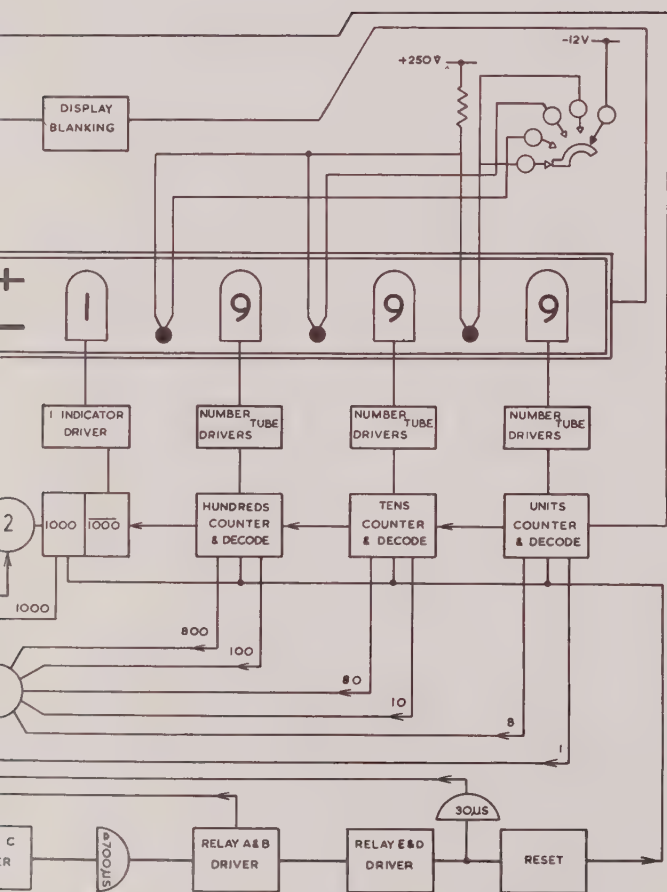


FIG. 3.3 OPERATIONAL WAVEFORMS

CIRCUIT DESCRIPTION

This description refers to circuit diagrams sheets 1, 2 and 3 at the rear of the manual. Reference will also be made to the Simplified Block Diagram and the Operational Waveforms [Figs. 3.2 and 3.3]. It should be appreciated that the waveforms of fig. 3.3 are simplified to clearly show the principles of operation and will not necessarily be exactly reproduced by waveforms displayed on an oscilloscope. Actual waveform photographs are shown in Fig. 5.5. The various circuit functions will be more readily understood if an assessment of some of the design principles is first made.

The LM 1619 Digital Voltmeter is a high-performance instrument of compact size and competitive price. Attention is given to simplicity of operation with a minimum of setting-up before use. This has been achieved by the complete elimination of zero drift resulting in a need for only one front panel preset calibration control. For industrial and systems applications rejection of common mode interference is an important feature and to this end the input terminals are maintained fully-floating. The full-scale reading of 1999 has been chosen to provide the most favourable range changeover point and hence excellent overall accuracy. The input resistance on the two basic ranges is defined by the combined leakage resistance of the input terminals, switching and associated wiring and will thus be dependent upon temperature and humidity but will remain in excess of 1000MΩ under all normal operating conditions.

Circuit Notes

The LM 1619 voltmeter circuitry is conveniently divided into two distinct sections; input amplifier and logic section [Printed Circuit Board 2]; Counter, decode and numerical indicator drivers [Printed Circuit Board 1]. The screening box assembly contains the components for the AC/DC Converter and the input attenuator and filter mounted on two additional printed circuit boards, nos. 1 and 2 respectively [circuit refs. 16199101 and 16199102]. Printed Circuit Board 4 carries the rectifying components for the power supply.

Board mounted components are shown enclosed by chain-dotted lines on the circuit diagrams and appear in the parts lists below the appropriate printed circuit board reference. All other components are chassis mounted and appear in the parts list headed "Main Assembly".

Interconnections

All printed circuit board interconnections are made with direct wiring. The interconnection pins of Printed Circuit Board 2 [circuit diagram sheet 1] are identified by numbers adjacent to the pins on the printed board and corresponding numbers on the circuit diagram. The output and interconnecting points of Printed Circuit Board 1 are all brought out to the pads of a 42-way printed circuit board edge-connector comb and thus the number and letter symbols on sheet 2 of the circuit diagram refer to this comb, as shown in the inset sketch. Edge-connector outputs are listed under the heading "Print-Out Information" [Section 1 Page 1.2].

Sheet 3 of the circuit diagram refers to the circuitry contained within the screening box assembly, reed relays and associated switching.

Input Attenuator, Filter and Range Switch:

The input attenuator and filter are contained in a screening box, isolated from the earth referenced input amplifier by the action of relays RLA, RLB, RLE and the storage capacitor C4. The screening box is connected to the instrument chassis earth via filter capacitor C7 and resistor R6 which define the isolation between terminals LO and CHASSIS as 200MΩ shunted by <1000pF.

On D.C. ranges switch [SA] selects combinations of the two values of attenuation together with two values of amplifier reference current to provide five ranges as shown in Table 4.1. Switch wafers SA3F/SA4F select the attenuation value and switch wafer SA1F the appropriate value of reference current. Switch wafer SA2F selects the decimal point indicator appropriate to the range in use. The contacts of switch wafer SA2R are available for the optional addition of range output information [details of this modification are included in Addendum 1 at the rear of the manual].

Range	Attenuation	Input Impedance	Ref. 1 Value
200mV	0	>1000MΩ	X1
2V	0		X10
20V	X100	10MΩ	X1
200V	X100		X10
1KV	X1000		X10

Table 3.1 INPUT RANGING

The sixth position of the range switch opens input HI and applies the saturated reference cell BY1 to the input, via switch wafer SA6F, providing a self-calibrating facility.

Overload Protection

The input circuitry of the digital voltmeter is not easily damaged by voltage overloads, but neon V1 and series limiting resistor R1 are included to extend the overload limits to the specified values of 350V on ranges 1 and 2 and up to 1000V on ranges 3, 4 and 5. Resistor R32 limits the input grid current of double-triode V1 under these conditions. This protection is not afforded to the AC/DC converter circuitry, which contains its own overload limiting components, but on AC ranges remains in circuit at the input of the D.C. section. Thus, if the overload limits for the AC ranges are exceeded, breakdown is restricted to the AC section only and the DC section remains undamaged.

Filter

Components R1/R6/R8/C5/C7 and C4 [RLE closed] form a permanently connected filter to provide 40dB of series mode rejection at 45Hz, increasing at 12dB per octave at higher frequencies. On AC ranges the filter provides additional smoothing of the AC/DC converter output.

AC/DC Converter

On AC ranges the input signal is applied via a frequency compensated attenuator to an R.M.S. scaled, mean-reading AC to DC converter [circuit diagram sheet 3] producing a DC output of 2 volts full-scale which is applied to the 2 volts basic range of the D.C. instrument. Three values of attenuation, 1000:1, 100:1 and 10:1 are used to provide, respectively, AC ranges of 750 volts, 200 volts and 20 volts. The input signal on the 2 volts range is applied directly to the AC/DC converter. The converter printed circuit board, together with its floating battery supply, is totally enclosed within the screening box assembly. Converter circuitry is designed for minimum current drain and a relay [RLF] is arranged to disconnect the batteries on all, other than AC, ranges or when the mains supply to the instrument is removed. The converter consists of a high open-loop gain direct-coupled amplifier feeding a full-wave rectifier circuit. The gain of the amplifier is defined by negative feedback such that the mean detected DC output is scaled to the R.M.S. equivalent value of the input signal.

The AC input signal, suitable attenuated, is applied across pins 1 and 3 of the converter printed circuit board. Pin 3 connects directly to input terminal

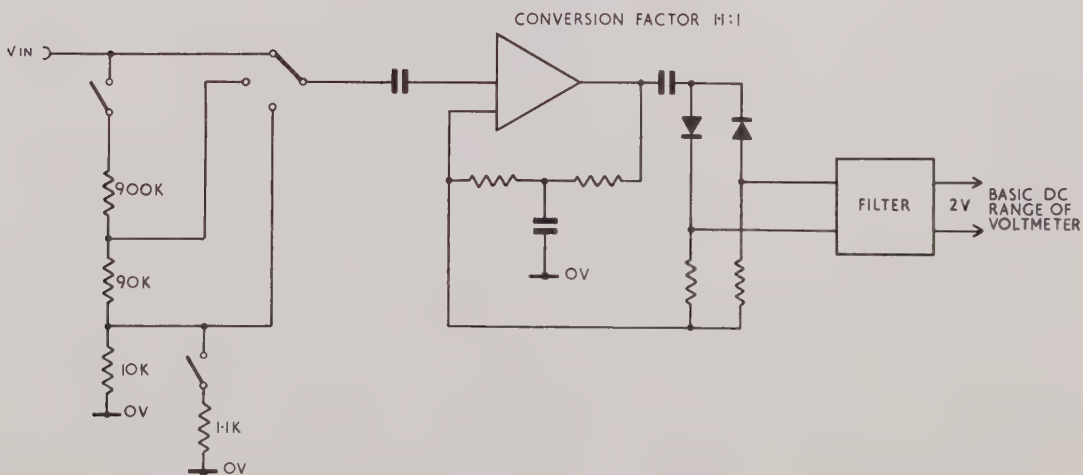


Fig. 3.4 AC/DC Converter Simplified Circuit

Hi on the 2 volt range, or via the attenuator on the other three ranges. Pin 1 is connected to input terminal Lo and to the floating battery zero volts rail. Capacitor C1 couples the input signal to the base of transistor VT1, which is protected by diodes MR6/MR7 and limiting resistor R16 against the inadvertent application of overload voltages. A high AC input impedance is obtained by bootstrapping the base-biasing network R1/R2/R3 via capacitor C2. Components C3/R5 provide H.F. roll-off above 10KHz to prevent phase-shift oscillation. The collector output of VT1 drives emitter follower VT2, the positive response of which is enhanced by "speed-up" capacitor C4. The amplifier output at VT3 collector is full-wave rectified by diodes MR4/MR5 and smoothed by components C7/C8/R14/R15. Transistor VT4 forms a constant current stage to linearise VT3 collector current and to provide a high effective load impedance. Diodes MR1/MR3 apply selective feedback, under overload conditions, to prevent saturation of the output stage. Overall DC feedback, to stabilise the amplifier, is taken from resistor R10, decoupled by capacitor C5, and the gain-defining AC feedback is taken from the dividers formed by resistors R11/R12, for positive half-cycles, and R11/R13, for negative half-cycles. Both forms of feedback are applied to the emitter of VT1. Preset resistor RV1 is included as a gain control for calibration purposes.

Input Amplifier

Double triode V1 forms the input stage to a virtual earth differential amplifier. The grid at pin 7 of V1 will be referred to as the signal input and the grid at pin 2 the differential input or virtual earth. In order to achieve optimum linearity over a comparatively wide range of signal amplitudes the stage is fed such that the anode-to-cathode voltage of the two triodes is held constant and the junction of their cathode loads is taken to a constant-current stage.

Transistor VT11 feeds resistor R42 with constant current, thus defining a constant anode-to-cathode voltage for the two halves of V1. The anode current of V1 is isolated from VT11 by the emitter follower VT13. Transistor VT12 forms a second constant current source, the difference between the two constant currents providing the anode current to V1. Additional stability is achieved by feeding the stage from the +90V reference supply.

Resulting from the charge-transfer technique used in the input circuitry the amplifier input impedance

is effectively multiplied by the mark/space ratio of the input relay chopping cycle, by an approximate factor of 25 at the input terminals of the voltmeter. Input error currents are reduced by the same factor. However, it is still necessary that the input amplifier should have a high input impedance and low grid current, both of which are achieved by operating the input triodes under electrometer conditions.

The outputs at the cathodes of V1 drive three direct-coupled, common-emitter, differential amplifiers with a total open-loop gain of approximately one million. Zener diode MR18 is included to stabilise transistor stage VT16/VT17 against mains-derived power-rail fluctuations.

Components C16/R13, connected between the collectors of transistors VT19/VT21, define the AC response of the amplifier, providing sufficient roll-off to prevent H.F. oscillation. Transistor VT25/VT26 form the output stage. The collector of VT26 is grounded and a single-ended output taken from the collector of VT25. It should be noted that the output at VT25 collector will be in-phase with the signal input and in reverse-phase with the differential input.

Amplifier Feedback and Charge Networks:

In the section headed "Technical Description", it was shown that the relays operate such that a negative input is applied to the amplifier signal input at the time that relay RLC is closed. Since there is 100% feed-back to the differential input, the final gain of the amplifier is unity. Thus the amplifier output rapidly charges the three parallel connected capacitors C18/C19/C20 to the value of the input voltage. Incidentally, capacitor C22 also charges to this level via transistor VT23, diode MR25 being reverse-biased at this time. In practice there is always a small offset voltage between the two amplifier inputs due to amplifier unbalance. However, since this offset is constant during the period of the measurement and the amplifier inputs return to this level at the conclusion of the charge transfer function the offset voltage will not be superimposed on the final ramp.

Capacitors C18/C19/C20 and C22 thus become fully charged to the value of the negative input signal, plus offset, and the next action is that contacts RLC/1 open and contacts RLD/1 close to zero volts via resistor R29. The amplifier output

swings rapidly positive and forward biases diode MR25 to close the loop with capacitive feedback, via C22. The gain of the amplifier is now defined by the ratio of input capacitance to feedback capacitance, approximately 20:1 and thus the final charge on C22 represents this figure plus the initial charge on C22. Transistor VT23, base referenced by zener diode MR20, forms a constant-current stage, limited by emitter resistor R91 to a maximum current of 500 microamps. This constant current stage, together with diode MR25, provides an approximately +6 volts bias level to ensure precise feedback switching levels at the commencement of the charge period and at the conclusion of the ramp. The bias level is short-term stable for the period between the feedback switching points and its effect on the duration of the output ramp is therefore negligible. Transistor VT28 forms an emitter switch to convert any negative excursion at the amplifier output, via diode MR28, into a suitable negative edge to drive detector transistor VT20.

+ 90 Volts Reference Supply

This supply is derived from the +250V rail via dropping resistor R4 and is shunt-stabilised by transistor VT27. The reference divider chain, including neon-stabiliser V2, is fed with constant current by the action of transistor VT27 and zener diode MR29. The reference voltage is thus stabilised against power rail fluctuations. The two values of reference current obtained from this supply are defined by resistors R90 and R92 and are in the region of 10 and 100 microamps respectively. The precise values are set during calibration using the three preset controls.

Reference Current Switching

Reference current is switched to the amplifier virtual earth, during the ramp-down period, via diode MR22. Prior to the ramp-down, reference current is diverted via diodes MR23/MR24 which are forward biased by the negative output from the "2000" bistable. At the conclusion of the ramp-down, reference current is again diverted, this time via MR23/MR26 forward biased by the amplifier output negative excursion. This later function [removing the reference current on the negative excursion], prevents the amplifier reaching a saturated end-stop condition. Diode MR27 limits the maximum positive amplifier output excursion during the charge transfer period by clamping the output to the +70V rail. The collector voltage of transistor VT25 could otherwise rise to +250V under

conditions of input overload, thereby exceeding its breakdown-voltage.

L.F. Multivibrator

Transistor VT6/VT8 form an emitter-coupled multivibrator to supply the drive waveform to operate the reed relay circuitry.

With mode switch [SB] at AUTO the circuit free-runs and produces negative-going pulses 20 milliseconds wide at an approximate repetition rate of two pulses per second.

Two outputs are taken from the emitter of transistor VT8, one to drive the base of relay RLC driver transistor VT9, and the other to drive the base of transistor VT4, the driver for relay RLA or relay RLB depending on the states of transistors VT3 and VT5. Components C12, MR12 and R40 form a network to delay the drive to transistor VT4 by approximately 700 microseconds. This ensures that relay RLC operates in advance of the remaining relays.

The multivibrator circuit time-constants are defined by capacitor C5, the long time-constant resistor R26 and the short time-constant resistor R23. Diode switching ensures a fast rise and fall to the output waveform and eliminates timing-errors produced by transistor leakage-current.

Consider transistor VT6 to be in the high-current state and transistor VT8 to be in the low-current state, with diode MR9 reverse-biased. Transistor VT6 is fed via resistor R23, diode MR8 and resistor R22 such that, in the high-current state, the collector voltage will be approximately at +6V. The base of transistor VT8, closely followed by its emitter, is connected to the collector of transistor VT6 and thus the output waveform also rests at approximately +6V. Capacitor C5 commences to charge via the long time-constant resistor R26 and contributes current, via diode MR8, to that already flowing in transistor VT6. The charge continues until the potential at diode MR9 anode rises above +6V. Diode MR9 conducts and the portion of VT6 collector current supplying the charge to C5 is thereby reduced, thus causing the collector voltage to move negatively. Transistor VT8 is in turn driven further into conduction and an accumulative positive feedback condition results producing a rapid negative-going output edge at VT8 emitter. This edge is transferred instantaneously via diode MR9 and capacitor C5 to the anode of

diode MR8 which is thereby reverse-biased. Transistor VT6 is thus switched to the low-current state, with its emitter current defined by R21 at approximately 50 microamps and its collector voltage at approximately -11 volts. The base of VT8, closely followed by the emitter, is connected to the collector of VT6 and thus the output waveform rests at approximately -10.5 volts. Capacitor C5 now commences to charge via the short time-constant resistor R23, diode MR9 and VT8 collector current, until the potential at the anode of diode MR8 exceeds +12V. The diode then conducts and current is diverted via VT6 collector current. The accumulative feedback action again takes place until VT8 is again in the low-current state with diode MR9 reverse-biased and VT6 rests in the high-current state with its emitter output at approximately +6V for the duration of the long time-constant.

Manual Operation

When the mode switch [SB] is set to MANUAL the anode of diode MR9 is held at approximately +2 volts by resistor R16 connected to the zero volts rail. The charge on capacitor C5 via resistor R26, is now unable to rise to the +6 volts level necessary to forward-bias diode MR9 and thus the circuit holds in the long time-constant state. Operation of SAMPLE button [SC] applies an instantaneous negative edge, via resistor R27 and capacitors C6 and C5, to diode MR8 anode initiating the short time-constant sequence. The output is thus a single negative pulse following each operation of the SAMPLE button.

Polarity Bistable and Relay Drive Circuitry:

Transistor VT1/VT2 form a conventional bistable circuit. Initially the bistable will switch to one of the two possible states, determined by circuit constants, and may then be reset by an output from the 2000 bistable, gated by detector transistor VT20, if an incorrect polarity is sensed. The 2000 bistable output is taken to the junction of resistor R82 and capacitor C21. The reset line to the polarity bistable is taken from the junction of C21 and R81 and fed to the gating diode MR1. Resistor R8 holds the cathode of MR1 to 0 volts. Should the detector output be at 0 volts at the time that the 2000 bistable switches to the 2000 state the positive-going edge, differentiated by C21 will pass via diode MR1, capacitors C1/C2 and the appropriate steering diode, MR2 or MR4 to cut-off the previously conducting transistor and thus switch the bistable to the correct polarity state.

The collector output from the "on" transistor is then fed to operate the appropriate relay switching and polarity indicator drive transistor, VT3 or VT5. Diodes MR6/MR7 isolate the two relay coils from the "off" neon. The relay driver is transistor VT4, driven on its base by the delayed output of the L.F. Multivibrator. Assuming a negative input to the instrument, transistor VT2 will be conducting with its collector at approximately 0 volts. The output from the junction of resistors R14/R15 will thus be at approximately -9.5 volts and transistor VT5 will conduct, illuminating the negative polarity indicator neon ILP2. When transistor VT4 receives the negative edge from the multivibrator on its base, diode MR7 is forward biased and relay RLB will operate closing contacts RLB/1 and RLB/2. Contacts RLE/1, RLE/2 and RLD/1 are required to open at the time that contacts RLA or RLB close and therefore transistor VT14 is made to be normally conducting, by virtue of bias network R46/R47/R48, and is switched off by the collector output of VT4 via diode MR14. Diode MR15 is included to eliminate the mutual damping effect of the parallel inductances of the relay coils during switch-off.

Transistor VT9 drives relay C from the direct output of the multivibrator.

Counter Reset

The positive edge produced at the collector of driver transistor VT14, to close the contacts of relays RLD and RLE, is fed, via diode MR17 and capacitor C14 to the base of transistor VT18. The collector output of VT18, a -10 volt pulse, is fed to the right-hand transistors of the units, tens, and hundreds bistables and to the left-hand transistor of the 1000 bistable. The counters are thus reset to 1000.

Detector

The function of transistor VT20 is to sense a negative output from the amplifier, 1999 gate or L.F. Multivibrator.

It would appear that VT20 is normally conducting due to forward bias from divider R68/R69/R70. However, under normal circumstances, the junction of resistors R69/R70 is held at 0 volts by one or more of the seven diodes connected to the 1999 gate line. The base of VT20 is thus held at approximately +3V and the transistor thereby held off. There are now three possible conditions which will produce an output from VT20: The anodes

of all seven 1999 gate diodes at -12V [1999 digitised]; amplifier output negative; negative pulse-period L.F. Multivibrator.

The detector circuit therefore appears as a logical NOR function, using negative logic [0 = 0 volts 1 = -12 volts], any one of three inputs at "1" producing a "0" output. The detector output provides one of the inputs to buffer stage VT22 and also, via resistors R80/R81, applies forward bias to diode MR1 to enable the polarity bistable to be reset by the 2000 bistable if the input signal changes sign.

Buffer

Transistor VT22 is the active element for a further NOR Circuit. Normally held off by the positive potential at its base via resistor R78, the transistor may be turned on by either of the two inputs, at the junction of resistors R79/R82, being at -12 volts [logical 1]. The collector will then be at 0 volts [logical 0] and this output is fed, via resistor R89, to open the steering-diodes MR1/MR2 of the first bistable of the units counter to allow the passage of clock pulses.

The condition at which clock pulses will not be fed to the counter is when both inputs are at 0 volts, which requires a "1" input to the detector and the 2000 bistable to be in the 2000 state.

Display Blanking

For the duration of the period that pulses are fed to the counter the display is blanked. When the collector of buffer transistor VT22 moves from -12 to 0 volts, the condition where pulses are gated to the counter, the base of blanking transistor VT24 moves to a level of approximately +4 volts, via resistor R88 and since VT24 is an NPN transistor it is thereby turned on. The collector of VT24 is connected to the anodes of the three blanking diodes MR34/MR35/MR36 and the anodes of the three numerical indicator tubes V1/V2/V3 are thereby taken to 0 volts and extinguished. The "1000" indicator neon lamp LP6 is blanked in a similar manner, via diode MR40.

Clock Oscillator

The pulses generated by this oscillator are gated by an output from buffer transistor VT22 and totalised in the display counter.

A series-resonant - mode, crystal - controlled oscillator [VT7] is employed, transformer T1 providing sufficient positive feedback to cause clipping. The output is thus in the form of pulses

suitable to drive the first bistable of the units counter. The output, via capacitor C8, is superimposed on a D.C. level obtained from the collector of buffer transistor VT22 via resistor R89 and is then fed to steering diodes MR1/MR2 of the units counter [Circuit Diagram Sheet 2]. Provided that VT22 collector is at 0 volts, pulses will be free to pass via the steering diodes to the units counter. A negative output at VT22 collector will hold both steering-diodes reverse-biased thus preventing further totalisation.

2000 Bistable

The 2000 bistable, transistors VT10/VT15, is so named because it accepts the carry pulse from the output of the 1000 bistable [Transistors VT55/VT56 circuit diagram sheet 2]. Its functions are, however, confined to switching logic and it does not contribute to the display [1999 full-scale].

The positive going carry pulse from the collector of the right-hand transistor of the 1000 bistable is applied to the base of transistor VT10 [2000 side] via capacitor C11 and diode MR13. To ensure that the 2000 bistable is not reset to the 2000 state before the time that reference current is switched, an inhibit, in the form of reverse-bias, is applied to the anode of diode MR13. This negative potential is obtained from the -12 volt rail via resistors R59/R56/R104 and is released by the collector of transistor VT14 moving to zero volts thus forward biasing MR17 at the time that relays RLD/RLE close. Capacitor C26 delays this moment of release by approximately 30 microseconds to ensure that the counter reset pulse, generated by transistor VT18, has completed. The 2000 set line conveys the positive edge from the L.F. Multivibrator, via capacitor C13 and steering diode MR16, to the base of transistor VT15.

The output from the 2000 side of the bistable, at VT15 collector, applies reverse bias to diode MR24 via resistor R93 to switch the reference current to the amplifier virtual earth. This same output provides one of the OR functions to the input of buffer transistor VT22 at the junction of R82/C21 and also, via C21, provides the positive edge to trip the polarity bistable if diode MR1 is forward biased by a "0" output from the detector via resistors R80/R81.

Power Supply Unit

General

The unit comprises a mains transformer and a printed - circuit board carrying the rectifying components,

Mains Input Circuit

The main transformer T1 is provided with a split primary winding capable of parallel or series connection to accommodate mains inputs within the range 98-132 or 184-265 volts. Transformer primary tap changing procedure is described under "Section 2 Operation, page 2.1".

Supply Circuit

The mains transformer is provided with two secondaries, the first of which, in conjunction with full-wave bridge MR1-MR4 and smoothing capacitor C3 provides the +250 volts rail. An additional supply of +70V is obtained from divider resistors R1/R2 and the +90V shunt-stabilised reference supply is taken from resistor R3. The second of the two secondaries is centre-tapped and provides two full-wave rectified supplies of +12V from diodes MR6/MR8 smoothed by capacitor C1, and -12V from diodes MR5/MR7 smoothed by capacitor C2. The power supplies are available at the edge connector of printed circuit board 1 and may be used to feed external circuitry provided that the maximum current-load ratings [as listed under "Print out Information" Section 1 Page 1.2] are not exceeded.

Display Counter

Three four-bistable, binary decade counters are employed for the hundreds, tens and units stages, and a single bistable one-count circuit for the one-thousand stage.

The units [first decade] counter is driven directly from the 100KHz clock oscillator. All decade counters are scaled to a count of ten by means of a diode trigger pulse gating system. The outputs from the three decade counters are fed to resistive networks for decoding from BCD to decimal form. Switching of the numerical indicator tubes is by transistor drive stages.

First Decade Counter and Decode

The input signal, in the form of a 6 volts amplitude pulse train, is taken from the collector of clock oscillator transistor VT7 via capacitor C8 and is superimposed on a gating level derived from the

collector output of VT22. The counter employs transistors VT2/VT3, VT6/VT8, VT10/VT13, VT15/VT18 connected in four symmetrical bistable circuits. Each bistable, except VT2/VT3, is provided with steering diodes and trigger capacitors [i.e. MR4/MR6, C5/C6 in the second bistable], to ensure that the positive triggering edge is applied to the base of the conducting transistor. In the first bistable, trigger capacitors are not included since the gating level is to be directly applied to the anodes of steering diodes MR1/MR2. At the commencement of each digitisation period, a negative reset pulse is generated by reset driver transistor VT18 and taken to the pin connected to edge connector pad 12. This reset pulse is applied to the 1, 2, 4 and 8 sides [VT3, VT8, VT13 and VT18] of the bistables to turn on these transistors and thus set the counter to the zero register condition in readiness for the impending count. The impulses counted progress through the stages in a conventional sequence up to the eighth pulse. During this period the positive triggering pulses from the collector of VT3 are passed to the base of VT8 via gating diode MR5, which is held in the forward-biased condition by the -12 volts potential present at the collector of the "off" transistor VT15. On receipt of the eighth pulse, the fourth stage bistable is switched to the "8" [VT15 conducting] condition and all other stages are set to the "1" condition [VT3, VT8, VT13 conducting]. As a result of VT15 collector going from -12 to zero volts, the forward bias is removed from MR5, and any output pulses appearing at VT3 collector are prevented from reaching the base of VT8. Thus the second [2] and the third [4] stages are inhibited from operation after the eighth pulse. The ninth pulse will therefore switch the first stage to the "1" condition [VT2 conducting] to effect a count of nine [8+1]. Finally, the positive output pulse from the first stage initiated by the tenth pulse is gated to bypass the second and third stages and switch the fourth stage to "8" [VT18 conducting] via C9 and MR9. Thus the counter is returned to zero, and the positive step developed at the collector of VT18 when that transistor is cut-on, provides the drive to the succeeding decade counter.

The method of decoding employed makes use of the fact that if the first stage bistable [1] is at "1" the numeral to be displayed must be an odd number. Conversely, if the "1" bistable is at "1" the displayed numeral must be an even number. Accordingly, the circuit is designed to inhibit the

operation of the transistor switches controlling the even or odd cathodes of the indicator tube having regard to the condition of the first stage bistable. The selection of the appropriate numeral from the non-inhibited numerals is then performed by a series of resistor gates monitoring the output of the second [2], third [4], and fourth [8] stage bistables.

Assume that the decade counter registers a count of nine [1 $\overline{2}$ $\overline{4}$ 8] since the first stage bistable is at "1" [VT2 conducting], the common emitter rail of the transistors [VT4, VT7, VT11, VT14 and VT17], switching the odd-numerals will be held at a potential of approximately -1.5 volts by the voltage drop developed across VT2 emitter resistor R5. Furthermore, the common-emitter rail of the transistors [VT1, VT5, VT9, VT12 and VT16] controlling the zero and even numerals will be held at a potential of approximately zero volts by the emitter resistor of the "off" transistor VT3. Thus, when the common base rail of a pair of transistors [i.e. VT1/VT4, VT5/VT7 etc] is taken positive, the odd-numeral switching transistors [VT4, VT7 etc] will conduct first by virtue of the 1.5 volts negative bias at their emitters. The base potentials of the transistor pairs are determined by the outputs [-12 or zero volts] from the counting bistables applied via a series of resistor gates. The common base potential of any transistor pair having one or more -12 volt inputs on the associated gate line or lines, will be held negative and both transistors will be cut-off. Conversely, the common base potential of any transistor pair having no -12 volt signals on any gate input, will stand positive, and that transistor whose common emitter rail is at -1.5 volts will conduct. In the present example which assumed that the counter was set for a count of nine, the bistable outputs will be as listed:-

2	0V
$\overline{2}$	-12V
4	0V
$\overline{4}$	-12V
8	-12V
$\overline{8}$	0V

It can be seen from the circuit diagram that in these circumstances the only pair of transistors whose common base potential can go positive is VT16/VT17. Since the emitter potential of VT17 is 1.5 volts

more negative than that of VT16, the former transistor will conduct first, thereby taking the common base potential to approximately -1 volt, and thus holding VT16 "off". The collector of VT17 is connected directly to the "9" indicator cathode [pin 11, V1] of the number tube enabling the neon to strike and display the number. The cathodes of all other numerals are connected to the collectors of the non-conducting transistors [VT1, VT4, VT5, VT7, VT9, VT11, VT12, VT14 and VT16] and are thus held, unable to strike.

Second and Third Decade Counters and Decode Circuits:

The Counter and Decode Circuits for the Tens and Hundreds Counters are identical with that of the units counter except that triggering capacitors are included on each counter input stage [C11/C14 and C21/C24].

1000 Bistable

A single bistable circuit VT55/VT56 is provided to make the "1000" count. The output from the collector of VT55 drives the base of VT57 to switch the "1000" indicator neon LP6 [located on Circuit Diagram Sheet 1].

1999 Gate

The outputs from the 1, 8, 10, 80, 100, 800, and 1000 sides of the bistable counters are taken to the "1999" line via diodes MR3, MR11, MR14, MR22, MR25, MR33 and MR39 respectively. When the instrument reaches a reading of "1999", the anodes of all diodes will stand at -12 volts forward biasing detector transistor VT20 and thereby inhibiting the further application of clock pulses to the counter input, through the action of buffer transistor VT22, thus preventing the counter from re-circulating to produce an invalid reading.

Fan-out

The edge-connector comb of P.C.B. 1, accessible at the rear of the instrument, provides direct connection to print-out information in the form of 1248 [B.C.D.] Code on 13 lines via 1000 Ω limiting resistors from the "1" side collectors of the display counter bistables. The outputs will drive a standard printer direct and may be loaded up to 1 milliamp. The "1" outputs from the bistables are also brought out to the edge-connector so that all bistable outputs are available for decoding to decimal form, if required. External limiting resistors should be fitted if the "1" outputs

are used. Polarity and print command [conversion complete] signals are provided, together with external sample command facility. The power rail outputs available at the edge-connector may be used to drive low-power external circuitry.

Complete details of logic levels are given in Section 1 under heading "Print Out" and pin assignments of the various functions are given under heading "Print Out Information".

NOTE

To provide satisfactory print-out from bi-polar inputs two samples should be commanded for each measurement to enable the instrument to accomplish a polarity reversal.

Optional Extra A suitable fan-out connector [Type EX1866], consisting of a 42-way free socket enclosed in a moulded plastic cover, is available as an optional extra.

SECTION 4

MAINTENANCE

The procedure described in the following paragraphs is basically the production test to which all LM 1619 Digital Voltmeters are subjected prior to dispatch. It is given to enable the user to confirm the performance of the instrument and to make any necessary adjustments. A 30 minute warm-up period should be allowed before calibration.

Test Equipment:

The following items of test equipment are required to carry out the procedure in its entirety. Type numbers of suitable Solartron instruments are given in brackets.

- 1] Avometer Model 8
- 2] Variac
- 3] Monitoring Oscilloscope [CD 1400]
- 4] Kintel Voltage Standard 303B
- 5] L.F. Oscillator [CO 546]
- 6] 20M Ω 1% Resistor
- 7] Weston-Rotek A.C. Standard AV 10

Case Removal:

Access to the instrument is obtained by removing the four Phillips screws from the rear plastic retainers [see fig. 2.1] and withdrawing the covers. To further improve accessibility the lower printed circuit board may be hinged outwards after removal of the T section front chassis support, held by two special extended screws, and the five board securing screws [see fig. 4.1].

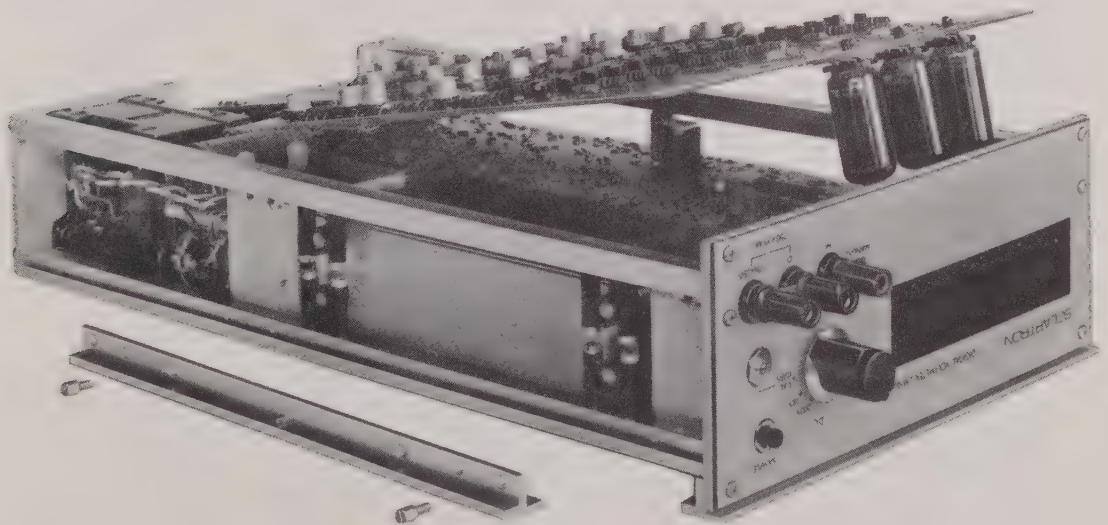


Fig 4. 1 Lower Board Access

Supply Rails Voltage Check:[for location of the supply rails see Fig. 4.2]

The supply rail voltages should be measured with the mains supply to the instrument set at the nominal voltage of 230V via the Variac, inputs HI, LO and CHASSIS shorted together and the mode switch at MANUAL. The voltages should be within the stated limits when measured with the Avometer with respect to zero volts. Ripple voltages are measured with the oscilloscope.

RAIL	LIMITS	RIPPLE
+250V	+250 $\pm$ 12.5V	<12V P/P
+90V*	+91.5 $\pm$ 2.5V	<50mV P/P
+70V	+70 $\pm$ 12.5V	<4V P/P
+12V	+12 $\pm$ 0.6V	<2V P/P
-12V	-12 $\pm$ 0.6V	<1.5V P/P

* NOTE: The stated limits for the +90V reference supply apply only with the front panel and internal preset CAL pots set fully clockwise. This measurement should therefore only be made if re-calibration of the instrument is anticipated.

Zero Check:

With terminals HI, LO and CHASSIS shorted, select AUTO mode and check that zero is displayed on all positions of the range switch except CAL and the battery check position.

With LO and CHASSIS linked and the range selector at 200mV apply an input of less than 150 μ V from the voltage standard [item 4 of Test Equipment]. Slowly increase the input level and check that the instrument begins to display 0002 within the range 150-250 μ V.

Set range selector to 2V and check that the instrument displays zero. Increase the input level in 100 μ V steps and check that the instrument begins to display 0001 within the range 500-1200 μ V. Repeat with input polarity reversed.

Timing Check:

With range selector at 2V apply an input of 1.8V and examine the amplifier output waveform [test point B fig. 4.6] with the oscilloscope [TIME CM: 10mS, Y SENSITIVITY: 10V/CM]. Measure the period between relay D closing and reference current switching [TIME "C" fig. 3.3] and check that this is 10 $\pm$ 1mS.

Check MANUAL and AUTO Sampling:

With range selector at 2V and an input of 1.8V select MANUAL and note that the reading is held.

Depress the SAMPLE button and check that one cycle of operation takes place.

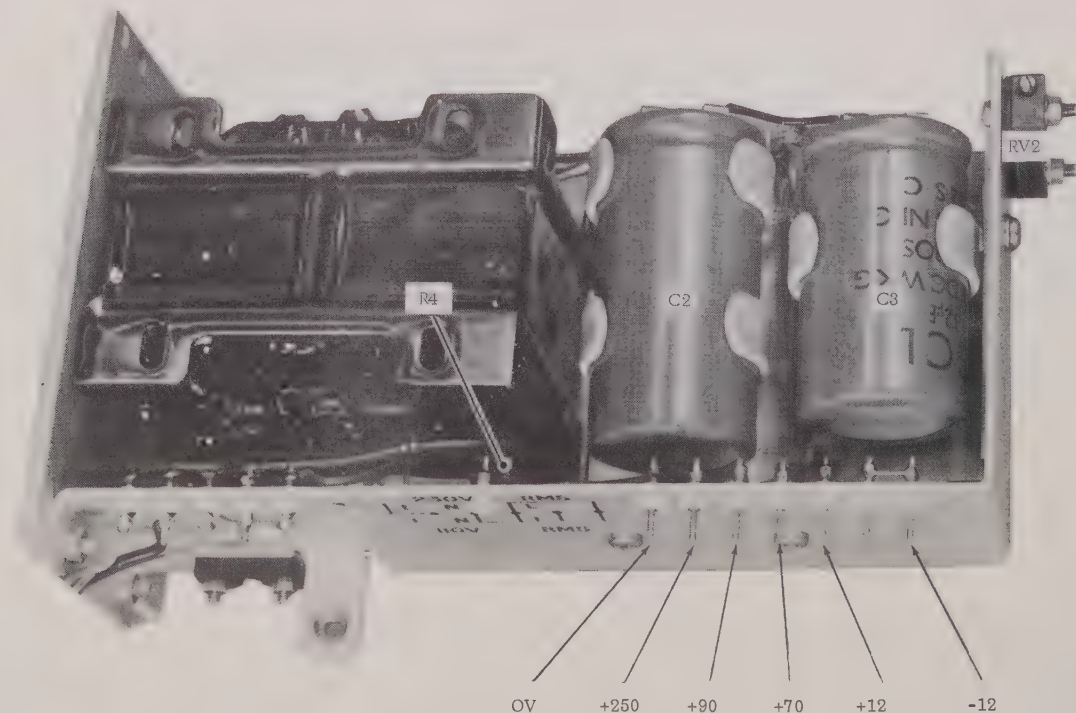


Fig 4.2 Power Rail Locations

Select AUTO mode and check that the number of samples taken during a period of 10 seconds is between 11 and 23.

Calibration of Basic Ranges (200mV and 2V):

With LO and CHASSIS linked and the range selector at 200mV, apply an input of 180mV from the voltage standard. Set front panel CAL pot to mid-range and adjust internal preset RV2 [located on power supply sub-chassis fig. 4.2] for a reading of 180.0. Set range selector to 2V and apply an input of 1.8V. Adjust RV1 [located on PCB 2, adjacent to valve bracket] for a reading of 1.800. Repeat 200mV range adjustment.

Set range selector to CAL and check that the display reads midway between 1.018 and 1.019.

NOTE Provided that the calibration source used for the previous steps has the required accuracy and the adjustments have been made as described, the reading obtained at this stage verifies the accuracy of the standard cell. [Expected E.M.F. decay <0.05% per year]. For external test point see fig. 4.6.

Calibration of D.C. Attenuated Ranges:

With terminals LO and CHASSIS linked apply inputs from the voltage standard to terminals HI and LO and adjust the appropriate preset pots [located within the attenuator screened box] as detailed. The screened box top cover is released by removing the two screws nearest the front panel. Resistors RV2 and RV3 are made accessible by slackening the front PCB retaining screw, removing the rear screw and then hinging the board upwards.

RANGE	INPUT	ADJUSTMENT	READING
20V	18V	RV2	18.00
200V	180V	CHECK RANGE	180.0
1KV	1000V	RV3	1000

Floating Input Zero Check:

With terminals HI and LO linked but not connected to CHASSIS the instrument should display 0000 $\pm$ 1 on the 200mV range. Remove link from HI and LO, and replace between LO and CHASSIS.

Input Impedance Check:

Apply inputs from the Voltage Standard to HI and LO via the 20M Ω resistor in series with signal HI. Readings within the limits stated correspond to an input impedance >2000M Ω .

RANGE	INPUT	READING
200mV	150mV	146.5 - 152.0
2V	1.5V	> 1.485

Input Current Check:

With LO and CHASSIS terminals linked and the range selector at 200mV, connect the 20M Ω resistor between HI and LO. Apply a temporary short across HI and LO and allow the instrument to settle at zero. Remove the short and check that the reading builds up to a steady value of less than 002.0 [2mV], corresponding to <10⁻¹⁰ A. Remove the 20M Ω resistor.

Linearity Check:

Select the 2V range and apply 1.9V from the Voltage Standard. Reduce the input level in 100mV steps down to 100mV, then in 10mV steps down to 10mV and finally in 1mV steps down to 0V.

Check that the readings obtained are accurate to within one bit throughout.

Series Mode Rejection Check:

Apply a signal of 5V rms at 45Hz, from the L.F. Oscillator to inputs HI and LO with the range selector at 2V and the mode switch at MANUAL. Measure the signal amplitude with the monitor oscilloscope across C4 [the 0.47 μ F capacitor mounted on standoffs at the rear of the attenuator screened box]. This signal should be <50mV r.m.s. [141 mV p.p.]. NOTE: The earthing lead of the oscilloscope must be connected to the inner standoff.

Common Mode Rejection Check:

A.C. Common Mode:

Remove the link between terminals LO and CHASSIS and select the 200mV range. Connect the circuit as shown in fig. 4.3 to HI and LO with the oscillator output set at zero. Increase the output to 3V r.m.s. and check that the reading varies by not more than 1mV.

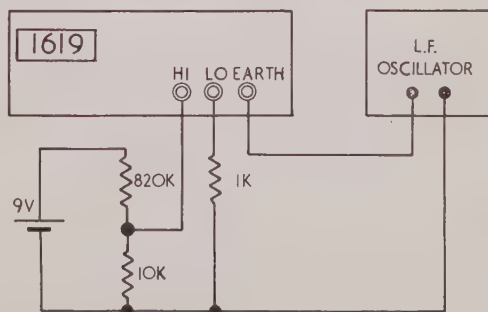


Fig. 4.3 AC Common Mode Test

D.C. Common Mode:

Connect the Circuit shown in fig. 4.4 to HI and LO and note the reading. Reverse the polarity of the DC supply and again note the reading. The largest of the two readings should be <25mV.

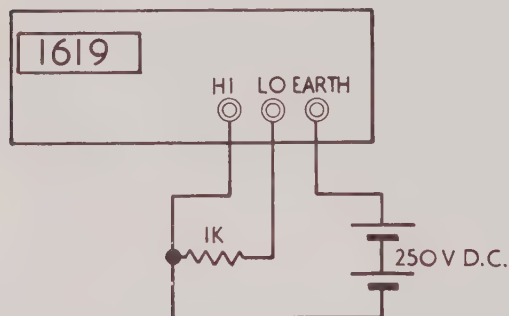


Fig. 4.4 DC Common Mode Test

Calibration of AC/DC Converter and AC Attenuated Ranges

Notes on Adjustment

The AC/DC converter circuitry is mounted on a second printed circuit board within the screened box. The single preset control RV1 is made accessible by hinging the board upwards, as previously described for the attenuator and filter board. Preliminary adjustments of the two AC attenuator presets, RV1 and RV4, mounted on the attenuator and filter board may be made with the screened box open and the board hinged up. Final adjustments of attenuator preset RV1 and the three frequency compensating preset capacitors C2, C3 and C4 should be made with both boards secured and the cover in place. These controls are then accessible through holes in the cover. Preset capacitors should be adjusted with a non-metallic trimming tool.

Adjustment Procedure

AC/DC Converter

Replace the link between terminals LO and CHASSIS. Switch to CAL and check for reading of 1,018/9, adjust if necessary. Select the 2V A.C. range and apply 1,800V R.M.S. at 400Hz from the A.C. Standard. [Item 7 of test equipment]. Adjust RV1 on the AC/DC converter board for a reading of 1,800. Check accuracy is maintained within 3 bits at frequencies of 50Hz, 1kHz, 5kHz and 10kHz.

AC Linearity Check

Select the 2V A.C. range and apply 1,900V R.M.S. at 400Hz from the A.C. Standard. Reduce the input level in 100mV steps down to 100mV, then in 10mV steps down to 10mV and finally in 1mV steps down

to 0 volts. Check that the readings obtained are accurate to within 1 bit throughout.

AC Attenuated Ranges

With terminals LO and CHASSIS linked, apply inputs at 400Hz from the A.C. Standard to terminals HI and LO. Adjust the appropriate preset pots mounted on the attenuator and filter board, as detailed.

RANGE	INPUT	ADJUSTMENT	READING
20V	18V	RV1	18.00
200V	180V	Check Range	180.0
750V	500V	RV4	500

Secure the two printed circuit boards and replace the screened box cover. Re-check the four A.C. ranges with appropriate 400Hz inputs from the A.C. Standard as previously applied. If necessary RV1, which is now accessible through a hole in the cover, may be re-adjusted to compensate for any overall change in readings.

AC Attenuator H.F. Compensation

Apply inputs at 10kHz from the A.C. Standard to terminals HI and LO. Adjust the appropriate preset capacitors, accessible through holes in the screened box cover, as detailed.

RANGE	INPUT	ADJUSTMENT	READING
20V	18V	C2	18.00
200V	180V	C3	180.0
750V	500V	C4	500

These capacitors interact so the adjustment should be repeated until all three ranges are correct.

Check AC Attenuator Frequency Response:

Apply inputs at the following frequencies to each range in turn with voltages as before:- 50Hz, 400Hz, 1kHz, 5kHz and 10kHz. Check that the readings are accurate to within 4 bits throughout.

AC Input Impedance

Select the 2V A.C. range and apply 1 volt at 400Hz from the A.C. Standard via a 100kΩ resistor in series with input HI. Check that the reading is >0.995. This corresponds to an input impedance >20MΩ.

Common Mode Rejection [AC ranges]

AC Common Mode

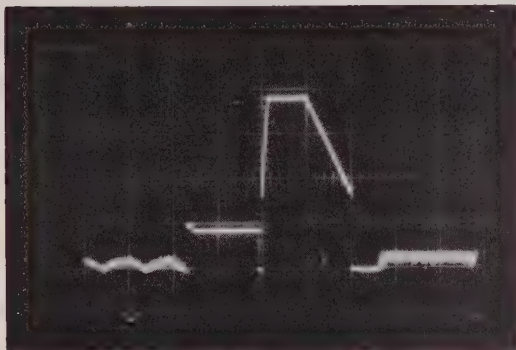
Remove the link between terminals LO and CHASSIS. Select the 2V range and connect a 1kΩ resistor between terminals HI and LO. Apply a common mode signal of 30V R.M.S. at 45Hz between the HI

terminal and CHASSIS. A display of not more than 0010 [10mV] should be obtained.

DC Common Mode

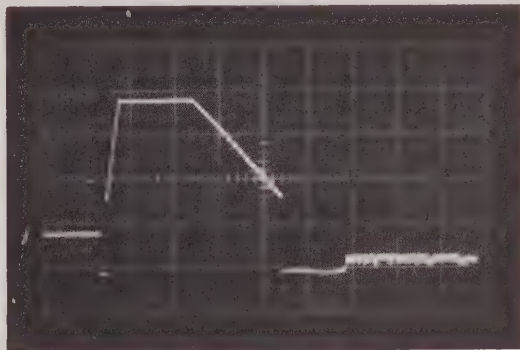
With conditions as for the previous test, apply 100V

D.C. Common mode signal between the HI terminal and CHASSIS. A display of not more than 0010 [10mV] should be obtained.



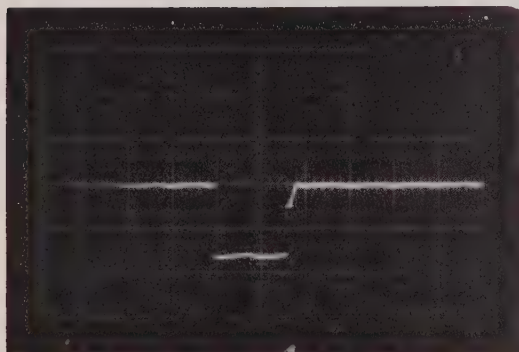
Amplifier Output Waveform
Deflection factor: 10V/cm.
Sweep time/cm.: 10mS.

Test Point B Fig. 4.6



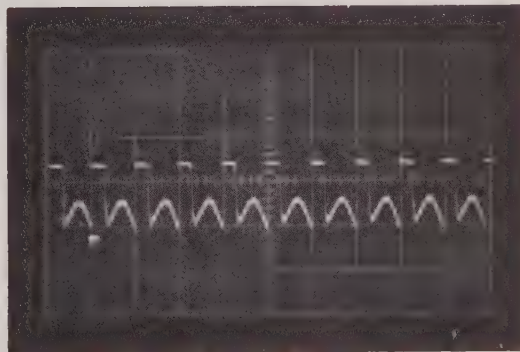
Amplifier Output Waveform
Deflection factor: 10V/cm.
Sweep time/cm.: 5mS.

Test Point B Fig. 4.6



L.F. Multivibrator Output
Deflection factor: 10V/cm
Sweep time/cm.: 10mS.

Test Point D Fig. 4.6

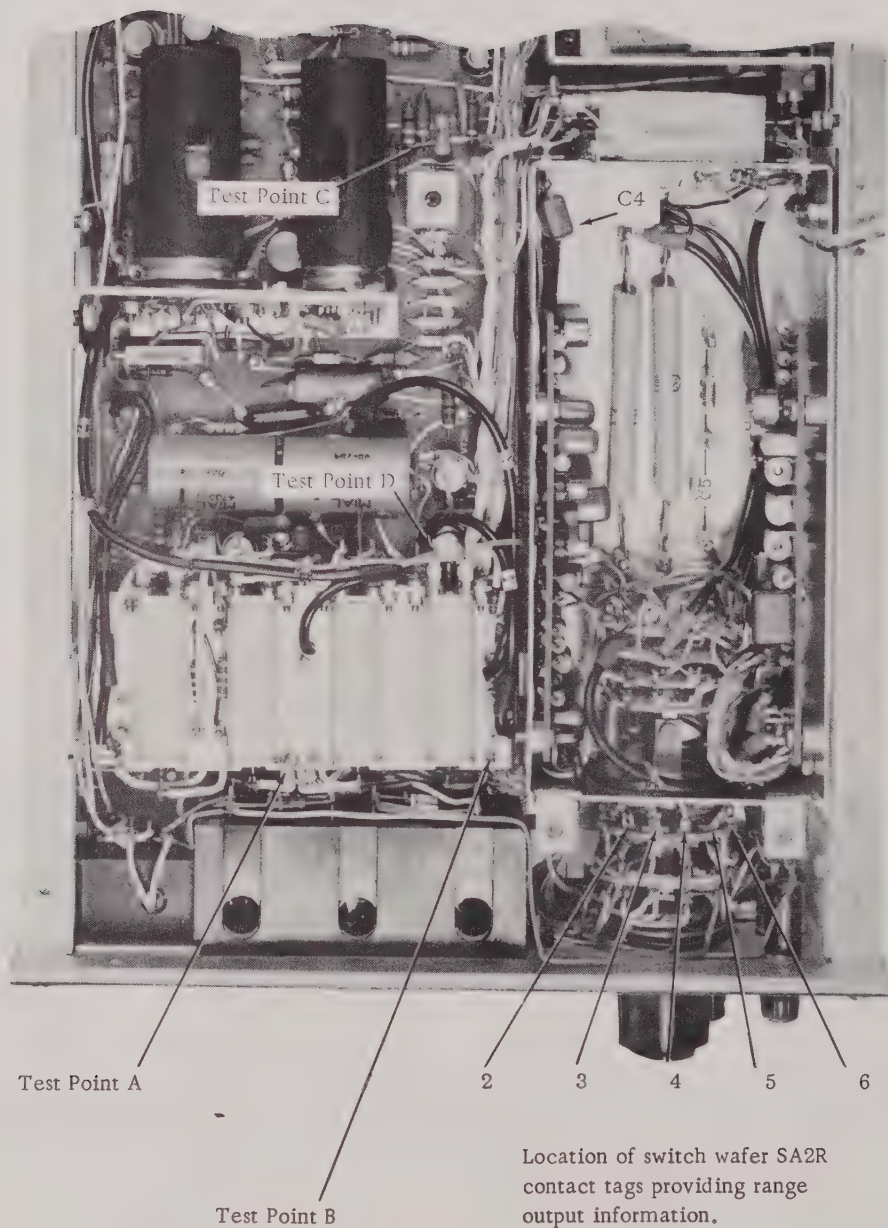


100kHz Clock Output
Deflection factor: 5V/cm.
Sweep time/cm.: 10μS.

Test Point C Fig. 4.6

The above photographs were taken with a standard oscilloscope camera fitted to a Solartron CD1220 oscilloscope incorporating a CX1256 wide-band plug-in amplifier and a CX1575 X10 compensated probe. LM1619 mode switch at AUTO range switch at CAL.

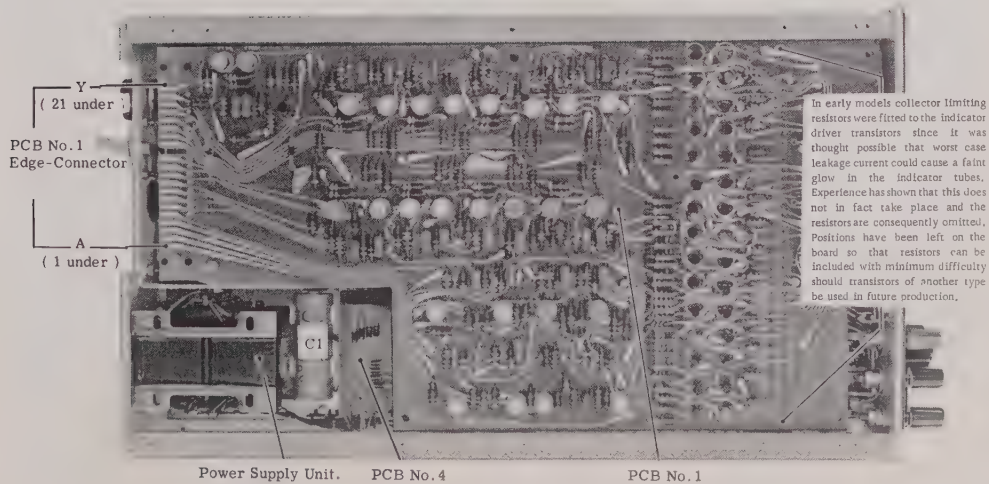
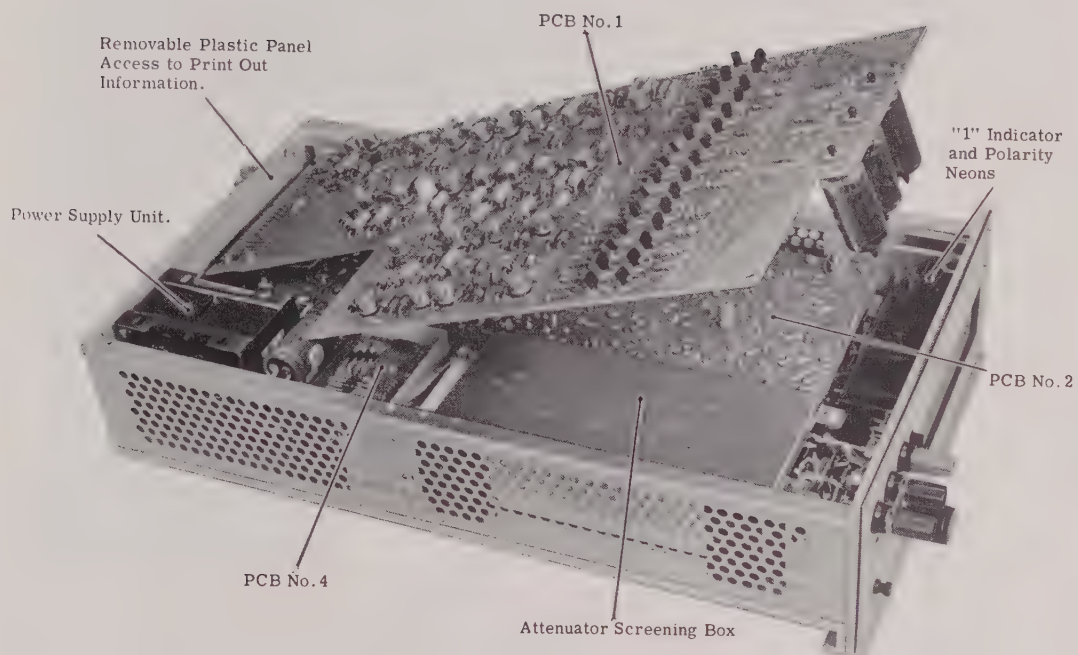
Fig 4.5 Typical Waveform Photographs



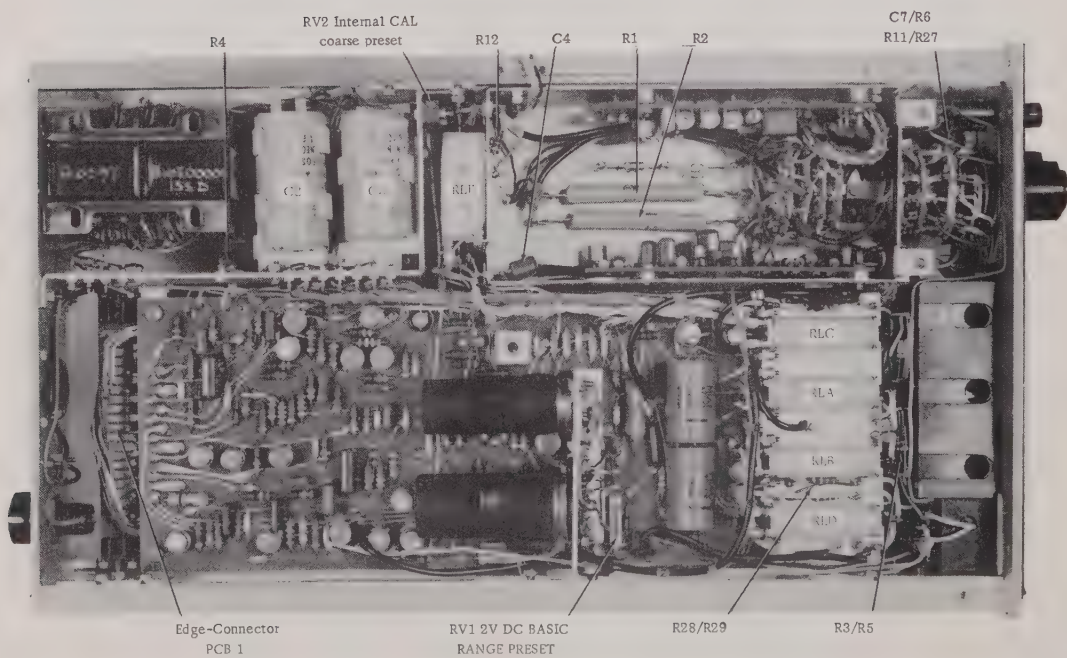
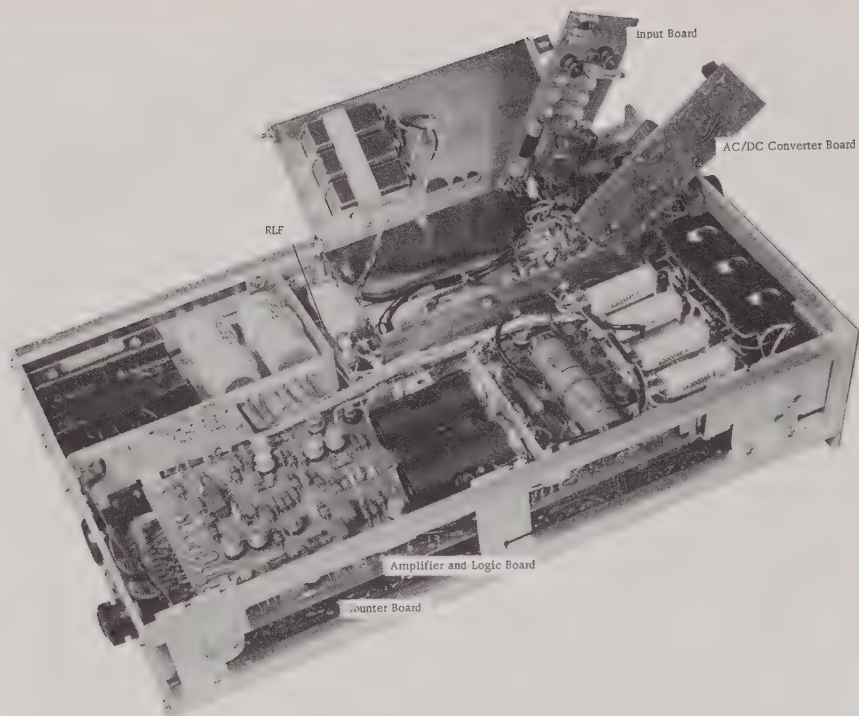
Test Point

- | | |
|---|--|
| A | Standard cell voltage measuring point, [range switch at CAL: mode switch at MANUAL]. Permanent connections should NOT be made to this point. |
| B | Amplifier output waveform. |
| C | 100KHz oscillator. |
| D | L.F. Multivibrator. |

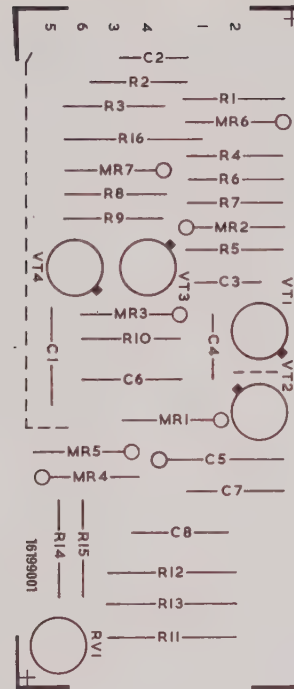
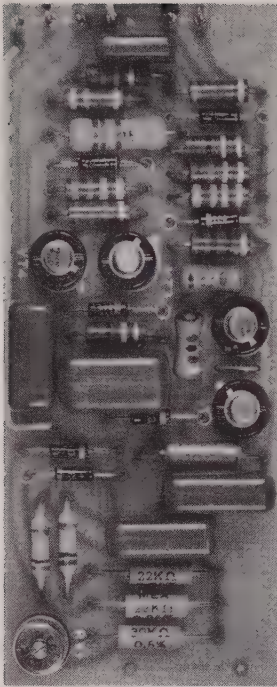
Fig. 4.6 Location of Test Points.



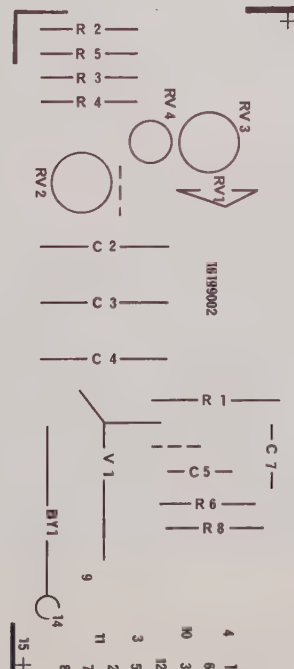
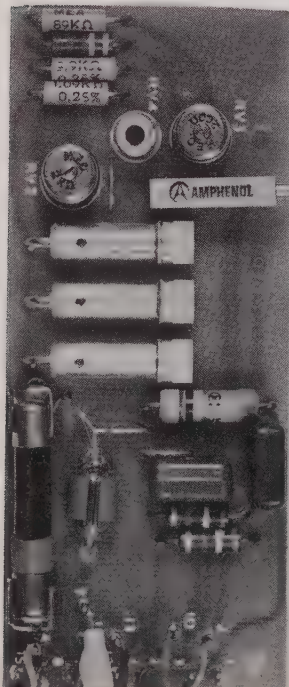
LM1619 Underside Views



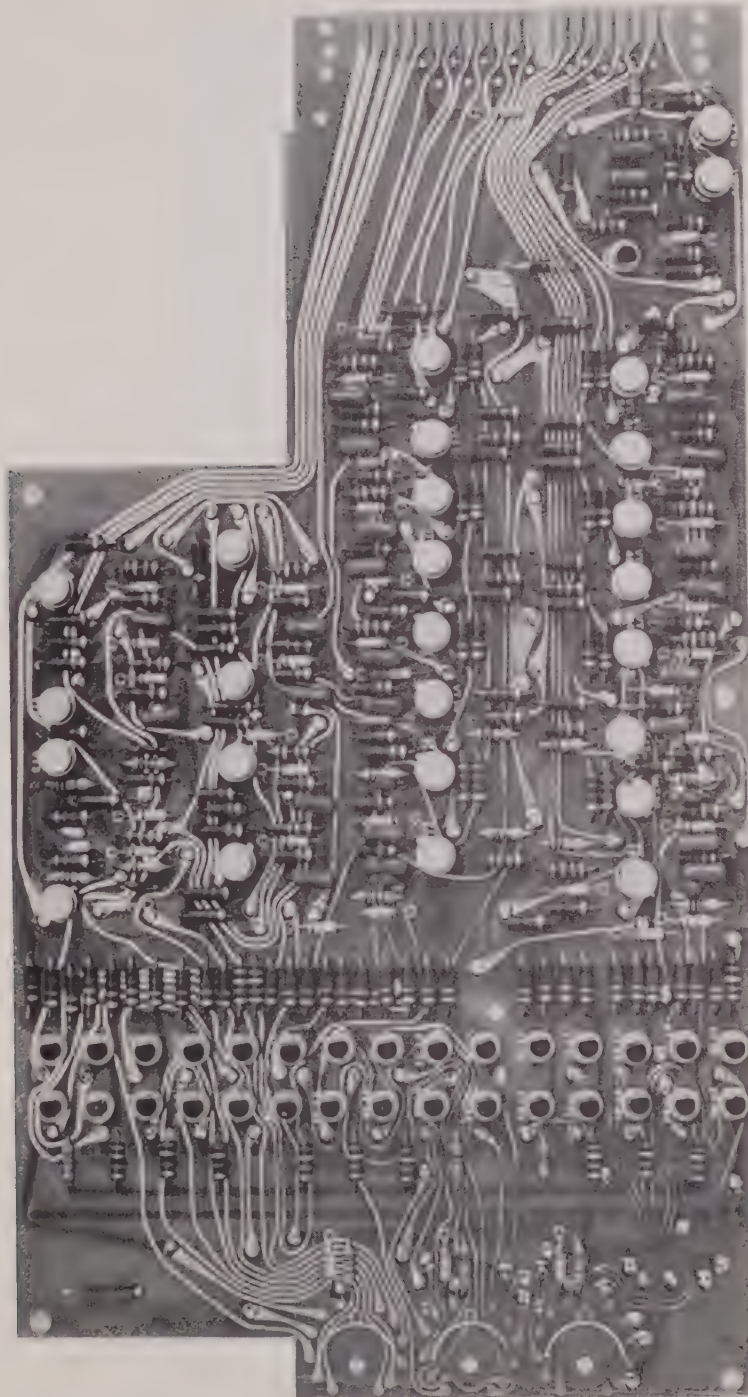
LM1619 Views from Above



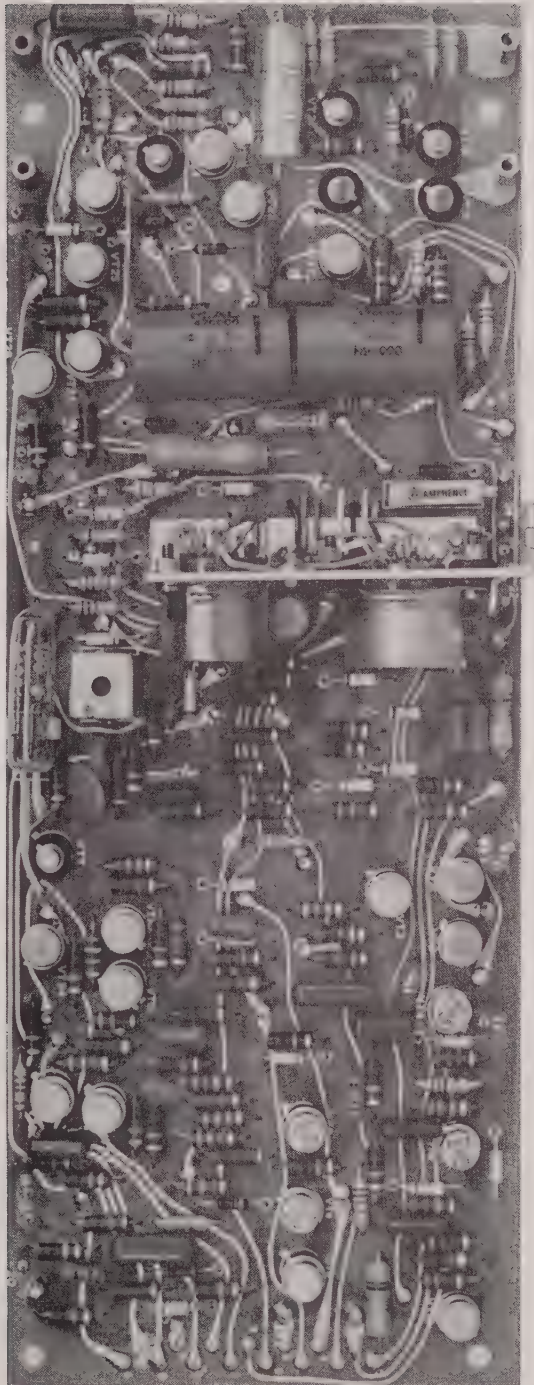
AC/DC Converter Board Assembly Component Location PCB No. 1 [Cct. ref. 16199101]



Input Board Assembly Component Location PCB No.2 [Cct. ref. 16199102]



Counter Board Assembly Component Layout PCB No. 1



Amplifier Board Assembly Component Layout PCB No. 2

COMPONENT PARTS LISTS

Component Parts List Abbreviations

Circuit Reference

R	Fixed Resistor (Ω)
RV	Variable Resistor (Ω)
C	Capacitor (μ F)
MR	Diode
VT	Transistor
V	Valve
S	Switch
RL	Relay
FS	Fuse
BY	Battery
T	Transformer
XL	Crystal
ILP	Lamp
RL	Relay

Component

V	Resistor Metal Film Insulated
W	Resistor Carbon, Insulated, Tolerance < 5%
X	Resistor Composition, Insulated Tolerance > 5%
Y	Resistor Wire Wound, Vitreous
Z	Resistor Oxide Film Insulated Tolerance < 5%
WW	Wire Wound
Po	Polyester
Ce. T	Ceramic Tube Ins.
Ce. D	Ceramic Disc Ins.
EI	Electrolytic
Pe	Polystyrene
Pe T	Polystyrene Tube Ins.

Component Parts List for Printed Circuit Board No. 1

Cct Ref	General Description				Solartron Part No.
R1	X	180K	$\frac{1}{2}$ W	10%	172351800
R2	Z	47K	$\frac{1}{2}$ W	5%	193544700
R3	Z	1000	$\frac{1}{2}$ W	5%	193531000
R4	X	6800	$\frac{1}{2}$ W	10%	172336800
R5	Z	100	$\frac{1}{2}$ W	5%	193521000
R6	X	33K	$\frac{1}{2}$ W	10%	172343300
R7	X	12K	$\frac{1}{2}$ W	10%	172341200
R8	X	12K	$\frac{1}{2}$ W	10%	172341200

Cct. Ref.	General Description				Solartron Part No.
R9	X	22K	$\frac{1}{2}$ W	10%	172342200
R10	Z	100	$\frac{1}{2}$ W	5%	193521000
R11	X	6800	$\frac{1}{2}$ W	10%	172336800
R12	X	1000	$\frac{1}{2}$ W	10%	172331000
R13	X	12K	$\frac{1}{2}$ W	10%	172341200
R14	Z	1000	$\frac{1}{2}$ W	5%	193531000
R15	X	180K	$\frac{1}{2}$ W	10%	172351800
R16	X	180K	$\frac{1}{2}$ W	10%	172351800
R17	X	10K	$\frac{1}{2}$ W	10%	172341000
R18	X	39K	$\frac{1}{2}$ W	10%	172343900
R19	X	1200	$\frac{1}{2}$ W	10%	172331200
R20	X	12K	$\frac{1}{2}$ W	10%	172341200
R21	X	10K	$\frac{1}{2}$ W	10%	172341000
R22	X	12K	$\frac{1}{2}$ W	10%	172345600
R23	X	56K	$\frac{1}{2}$ W	10%	172345600
R24	X	39K	$\frac{1}{2}$ W	10%	172343900
R25	X	1000	$\frac{1}{2}$ W	10%	172331000
R26	X	180K	$\frac{1}{2}$ W	10%	172351800
R27	X	10K	$\frac{1}{2}$ W	10%	172341000
R28	X	1200	$\frac{1}{2}$ W	10%	172331200
R29	X	180K	$\frac{1}{2}$ W	10%	172351800
R30	X	10K	$\frac{1}{2}$ W	10%	172341000
R31	X	39K	$\frac{1}{2}$ W	10%	172343900
R32	X	12K	$\frac{1}{2}$ W	10%	172341200
R33	X	10K	$\frac{1}{2}$ W	10%	172341000
R34	X	1200	$\frac{1}{2}$ W	10%	172331200
R35	X	12K	$\frac{1}{2}$ W	10%	172341200
R36	X	10K	$\frac{1}{2}$ W	10%	172341000
R37	X	180K	$\frac{1}{2}$ W	10%	172351800
R38	X	56K	$\frac{1}{2}$ W	10%	172345600
R39	X	15K	$\frac{1}{2}$ W	10%	172341500
R40	X	39K	$\frac{1}{2}$ W	10%	172343900
R41	X	1000	$\frac{1}{2}$ W	10%	172331000
R42	X	180K	$\frac{1}{2}$ W	10%	172351800
R43	X	10K	$\frac{1}{2}$ W	10%	172341000
R44	X	1200	$\frac{1}{2}$ W	10%	172331200
R45	X	39K	$\frac{1}{2}$ W	10%	172343900
R46	X	10K	$\frac{1}{2}$ W	10%	172341000
R47	X	12K	$\frac{1}{2}$ W	10%	172341200
R48	X	12K	$\frac{1}{2}$ W	10%	172341200
R49	X	180K	$\frac{1}{2}$ W	10%	172351800
R50	X	10K	$\frac{1}{2}$ W	10%	172341000
R51	X	1500	$\frac{1}{2}$ W	10%	172331500
R52	X	180K	$\frac{1}{2}$ W	10%	172351800
R53	X	10K	$\frac{1}{2}$ W	10%	172341000
R54	X	39K	$\frac{1}{2}$ W	10%	172343900
R55	X	56K	$\frac{1}{2}$ W	10%	172345600
R56	X	12K	$\frac{1}{2}$ W	10%	172341200
R57	X	39K	$\frac{1}{2}$ W	10%	172343900
R58	X	180K	$\frac{1}{2}$ W	10%	172351800
R59	X	1000	$\frac{1}{2}$ W	10%	172331000
R60	X	10K	$\frac{1}{2}$ W	10%	172341000

Cct. Ref.	General Description					Solartron Part No.	Cct. Ref.	General Description					Solartron Part No.
R61	X	1500	$\frac{1}{2}$ W	10%		172331500	R118	X	39K	$\frac{1}{2}$ W	10%		172343900
R62	X	10K	$\frac{1}{2}$ W	10%		172341000	R119	X	56K	$\frac{1}{2}$ W	10%		172345600
R63	X	10K	$\frac{1}{2}$ W	10%		172341000	R120	X	12K	$\frac{1}{2}$ W	10%		172341200
R64	X	180K	$\frac{1}{2}$ W	10%		172351800	R121	X	39K	$\frac{1}{2}$ W	10%		172343900
R65	Z	47K	$\frac{1}{2}$ W	5%		193544700	R122	X	10K	$\frac{1}{2}$ W	10%		172341000
R66	Z	1000	$\frac{1}{2}$ W	5%		193531000	R123	X	1000	$\frac{1}{2}$ W	10%		172331000
R67	X	6800	$\frac{1}{2}$ W	10%		172336800	R124	X	180K	$\frac{1}{2}$ W	10%		172351800
R68	Z	100	$\frac{1}{2}$ W	5%		193521000	R125	X	1500	$\frac{1}{2}$ W	10%		172331500
R69	X	33K	$\frac{1}{2}$ W	10%		172343300	R126	X	10K	$\frac{1}{2}$ W	10%		172341000
R70	X	12K	$\frac{1}{2}$ W	10%		172341200	R127	X	10K	$\frac{1}{2}$ W	10%		172341000
R71	X	12K	$\frac{1}{2}$ W	10%		172341200	R128	X	180K	$\frac{1}{2}$ W	10%		172351800
R72	X	22K	$\frac{1}{2}$ W	10%		172342200	R129	Z	100	$\frac{1}{2}$ W	5%		193521000
R73	X	6800	$\frac{1}{2}$ W	10%		172336800	R130	Z	1000	$\frac{1}{2}$ W	5%		193531000
R74	X	1000	$\frac{1}{2}$ W	10%		172331000	R131	X	6800	$\frac{1}{2}$ W	10%		172336800
R75	X	12K	$\frac{1}{2}$ W	10%		172341200	R132	Z	47K	$\frac{1}{2}$ W	5%		193544700
R76	Z	100	$\frac{1}{2}$ W	5%		193521000	R133	X	33K	$\frac{1}{2}$ W	10%		172343300
R77	Z	1000	$\frac{1}{2}$ W	5%		193531000	R134	X	12K	$\frac{1}{2}$ W	10%		172341200
R78	X	180K	$\frac{1}{2}$ W	10%		172351800	R135	X	12K	$\frac{1}{2}$ W	10%		172341200
R79	X	10K	$\frac{1}{2}$ W	10%		172341000	R136	X	22K	$\frac{1}{2}$ W	10%		172342200
R80	X	180K	$\frac{1}{2}$ W	10%		172351800	R137	X	1000	$\frac{1}{2}$ W	10%		172331000
R81	X	10K	$\frac{1}{2}$ W	10%		172341000	R138	X	6800	$\frac{1}{2}$ W	10%		172336800
R82	X	39K	$\frac{1}{2}$ W	10%		172343900	R139	X	12K	$\frac{1}{2}$ W	10%		172341200
R83	X	12K	$\frac{1}{2}$ W	10%		172341200	R140	Z	100	$\frac{1}{2}$ W	5%		193521000
R84	X	1200	$\frac{1}{2}$ W	10%		172331200	R141	Z	1000	$\frac{1}{2}$ W	5%		193531000
R85	X	10K	$\frac{1}{2}$ W	10%		172341000	R142	X	180K	$\frac{1}{2}$ W	10%		172351800
R86	X	12K	$\frac{1}{2}$ W	10%		172341200	R143	X	10K	$\frac{1}{2}$ W	10%		172341000
R87	X	56K	$\frac{1}{2}$ W	10%		172345600	R144	X	180K	$\frac{1}{2}$ W	10%		172351800
R88	X	180K	$\frac{1}{2}$ W	10%		172351800	R145	X	39K	$\frac{1}{2}$ W	10%		172343900
R89	X	1000	$\frac{1}{2}$ W	10%		172331000	R146	X	10K	$\frac{1}{2}$ W	10%		172341000
R90	X	39K	$\frac{1}{2}$ W	10%		172343900	R147	X	1200	$\frac{1}{2}$ W	10%		172331200
R91	X	10K	$\frac{1}{2}$ W	10%		172341000	R148	X	12K	$\frac{1}{2}$ W	10%		172341200
R92	X	1200	$\frac{1}{2}$ W	10%		172331200	R149	X	10K	$\frac{1}{2}$ W	10%		172341000
R93	X	180K	$\frac{1}{2}$ W	10%		172351800	R150	X	56K	$\frac{1}{2}$ W	10%		172345600
R94	X	10K	$\frac{1}{2}$ W	10%		172341000	R151	X	12K	$\frac{1}{2}$ W	10%		172341200
R95	X	39K	$\frac{1}{2}$ W	10%		172343900	R152	X	180K	$\frac{1}{2}$ W	10%		172351800
R96	X	12K	$\frac{1}{2}$ W	10%		172341200	R153	X	39K	$\frac{1}{2}$ W	10%		172343900
R97	X	10K	$\frac{1}{2}$ W	10%		172341000	R154	X	10K	$\frac{1}{2}$ W	10%		172341000
R98	X	12K	$\frac{1}{2}$ W	10%		172341200	R155	X	1000	$\frac{1}{2}$ W	10%		172331000
R99	X	1200	$\frac{1}{2}$ W	10%		172331200	R156	X	1200	$\frac{1}{2}$ W	10%		172331200
R100	X	10K	$\frac{1}{2}$ W	10%		172341000	R157	X	180K	$\frac{1}{2}$ W	10%		172351800
R101	X	180K	$\frac{1}{2}$ W	10%		172351800	R158	X	10K	$\frac{1}{2}$ W	10%		172341000
R102	X	56K	$\frac{1}{2}$ W	10%		172345600	R159	X	39K	$\frac{1}{2}$ W	10%		172343900
R103	X	15K	$\frac{1}{2}$ W	10%		172341500	R160	X	12K	$\frac{1}{2}$ W	10%		172341200
R104	X	39K	$\frac{1}{2}$ W	10%		172343900	R161	X	10K	$\frac{1}{2}$ W	10%		172341000
R105	X	1000	$\frac{1}{2}$ W	10%		172331000	R162	X	12K	$\frac{1}{2}$ W	10%		172341200
R106	X	180K	$\frac{1}{2}$ W	10%		172351800	R163	X	1200	$\frac{1}{2}$ W	10%		172331200
R107	X	10K	$\frac{1}{2}$ W	10%		172341000	R164	X	10K	$\frac{1}{2}$ W	10%		172341000
R108	X	1200	$\frac{1}{2}$ W	10%		172331200	R165	X	56K	$\frac{1}{2}$ W	10%		172345600
R109	X	39K	$\frac{1}{2}$ W	10%		172343900	R166	X	180K	$\frac{1}{2}$ W	10%		172351800
R110	X	12K	$\frac{1}{2}$ W	10%		172341200	R167	X	15K	$\frac{1}{2}$ W	10%		172341500
R111	X	10K	$\frac{1}{2}$ W	10%		172341000	R168	X	39K	$\frac{1}{2}$ W	10%		172343900
R112	X	12K	$\frac{1}{2}$ W	10%		172341200	R169	X	10K	$\frac{1}{2}$ W	10%		172341000
R113	X	180K	$\frac{1}{2}$ W	10%		172351800	R170	X	180K	$\frac{1}{2}$ W	10%		172341000
R114	X	10K	$\frac{1}{2}$ W	10%		172341000	R171	X	39K	$\frac{1}{2}$ W	10%		172343900
R115	X	1500	$\frac{1}{2}$ W	10%		172331500	R172	X	1200	$\frac{1}{4}$ W	10%		172331200
R116	X	180K	$\frac{1}{2}$ W	10%		172351800	R173	X	12K	$\frac{1}{2}$ W	10%		172341200
R117	X	10K	$\frac{1}{2}$ W	10%		172341000	R174	X	10K	$\frac{1}{2}$ W	10%		172341000

Cct. Ref.	General Description				Solartron Part No.	Cct. Ref.	General Description			Solartron Part No.
R175	X	12K	$\frac{1}{2}$ W	10%	172341200	MR1				
R176	X	180K	$\frac{1}{2}$ W	10%	172351800	to	SD1			300520070
R177	X	10K	$\frac{1}{2}$ W	10%	172341000	MR39				
R178	X	180K	$\frac{1}{2}$ W	10%	172351800	MR40	IN4004	Motorola		300522070
R179	X	1500	$\frac{1}{2}$ W	10%	172331500					
R180	X	10K	$\frac{1}{2}$ W	10%	172341000	VT1	A1778/2	Fairchild		300551430
R181	X	39K	$\frac{1}{2}$ W	10%	172343900	VT2	D535	Texas Inst		300551620
R182	X	56K	$\frac{1}{2}$ W	10%	172345600	VT3	D545	Texas Inst		300551620
R183	X	39K	$\frac{1}{2}$ W	10%	172343900	VT4	A1778/2	Fairchild		300551430
R184	X	10K	10%			VT5	A1778/2	Fairchild		300551430
R184	X	10K	$\frac{1}{2}$ W	10%	172341000	VT6	D535	Texas		300551620
R185	X	1000	$\frac{1}{2}$ W	10%	172331000	VT7	A1778/2	Fairchild		300551430
R186	X	12K	$\frac{1}{2}$ W	10%	172341200	VT8	D535	Texas		300551620
R187	X	180K	$\frac{1}{2}$ W	10%	172351800	VT9	A1778/2	Fairchild		300551430
R188	X	1500	$\frac{1}{2}$ W	10%	172331500	VT10	D535	Texas		300551620
R189	X	10K	$\frac{1}{2}$ W	10%	172341000	VT11	A1778/2	Fairchild		300551430
R190	Z	56K	$\frac{1}{2}$ W	5%	193545600	VT12	A1778/2	Fairchild		300551430
R191	Z	56K	$\frac{1}{2}$ W	5%	193545600	VT13	D535	Texas		300551620
R192	Z	56K	$\frac{1}{2}$ W	5%	193545600	VT14	A1778/2	Fairchild		300551430
R193	X	10K	$\frac{1}{2}$ W	10%	172341000	VT15	D535	Texas		300551620
R194	X	1500	$\frac{1}{2}$ W	10%	172331500	VT16	A1778/2	Fairchild		300551430
R195	X	10K	$\frac{1}{2}$ W	10%	172341000	VT17	A1778/2	Fairchild		300551430
R196	X	56K	$\frac{1}{2}$ W	10%	172345600	VT18	D535	Texas		300551620
R197	X	39K	$\frac{1}{2}$ W	10%	172343900	VT19	A1778/2	Fairchild		300551430
R198	X	10K	$\frac{1}{2}$ W	10%	172341000	VT20	D535	Texas		300551620
R199	X	1500	$\frac{1}{2}$ W	10%	172331500	VT21	D535	Texas		300551620
R200	X	10K	$\frac{1}{2}$ W	10%	172341000	VT22	A1778/2	Fairchild		300551430
R201	X	15K	$\frac{1}{2}$ W	10%	172341500	VT23	A1778/2	Fairchild		300551430
R202	X	39K	$\frac{1}{2}$ W	10%	172343900	VT24	D535	Texas		300551620
R203	X	1000	$\frac{1}{2}$ W	10%	172331000	VT25	A1778/2	Fairchild		300551430
R204	Z	150K	$\frac{1}{2}$ W	5%	193551500	VT26	D535	Texas		300551620
R205	X	1000	$\frac{1}{2}$ W	10%	172331000	VT27	A1778/2	Fairchild		300551430
						VT28	D535	Texas		300551620
						VT29	A1778/2	Fairchild		300551430
						VT30	A1778/2	Fairchild		300551430
C1	Ce. D	0.1	3V	-0 +100%	208450076	VT31	D535	Texas		300551620
C2	Pe. T	470p	30V	20%	208100130	VT32	A1778/2	Fairchild		300551430
C3	Pe. T	470p	30V	20%	208100130	VT33	D535	Texas		300551620
C4	Ce. D	0.1	3V	-0 +100%	208450076	VT34	A1778/2	Fairchild		300551430
C5						VT35	A1778/2	Fairchild		300551430
to	Ce. T	470p	500V	10%	208400084	VT36	D535	Texas		300551620
C11						VT37	A1778/2	Fairchild		300551430
						VT38	D535	Texas		300551620
C12	Ce. D	0.1	3V	-0 +100%	208450076	VT39	D535	Texas		300551620
						VT40	A1778/2	Fairchild		300551430
C13	Ce. D	0.1	3V	-0 +100%	208450076	VT41	A1778/2	Fairchild		300551430
						VT42	D535	Texas		300551620
C14						VT43	A1778/2	Fairchild		300551430
to	Ce. T	470p	500V	10%	208400084	VT44	D535	Texas		300551620
C21						VT45	A1778/2	Fairchild		300551430
						VT46	D535	Texas		300551620
C22	Ce. D	0.1	3V	-0 +100%	208450076	VT47	A1778/2	Fairchild		300551430
						VT48	A1778/2	Fairchild		300551430
C23	Ce. D	0.1	3V	-0 +100%	208450076	VT49	D535	Texas		300551620
						VT50	A1778/2	Fairchild		300551430
C24						VT51	D535	Texas		300551620
to	Ce. T	470p	500V	10%	208400084	VT52	A1778/2	Fairchild		300551430
C32										

Cct Ref.	General Description		Solartron Part No.
VT53	A1778/2	Fairchild	300551430
VT54	D535	Texas	300551620
VT55	D535	Texas	300551620
VT56	D535	Texas	300551620
VT57	A1778/2	Fairchild	300551430
V1 to V3	ZM1080	Mullard	300011330

**Component Parts List
for
Printed Circuit Board No.2**

Cct. Ref.	General Description				Solartron Part No.
R1	X	10K	$\frac{1}{2}$ W	10%	172341000
R2	X	3300	$\frac{1}{2}$ W	10%	172333300
R3	X	1000	$\frac{1}{2}$ W	10%	172331000
R4	X	2200	$\frac{1}{2}$ W	10%	172332200
R5	X	1000	$\frac{1}{2}$ W	10%	172331000
R6	X	10K	$\frac{1}{2}$ W	10%	172341000
R7	X	47K	$\frac{1}{2}$ W	10%	172344700
R8	X	22K	$\frac{1}{2}$ W	10%	172342200
R9	X	47K	$\frac{1}{2}$ W	10%	172344700
R10	X	10K	$\frac{1}{2}$ W	10%	172341000
R11	X	1000	$\frac{1}{2}$ W	10%	172331000
R12	X	2200	$\frac{1}{2}$ W	10%	172332200
R13	X	10K	$\frac{1}{2}$ W	10%	172341000
R14	X	3300	$\frac{1}{2}$ W	10%	172333300
R15	X	1000	$\frac{1}{2}$ W	10%	172331000
R16	X	100K	$\frac{1}{2}$ W	10%	172351000
R17	X	180K	$\frac{1}{2}$ W	10%	172351000
R18	X	1500	$\frac{1}{2}$ W	10%	192331500
R19	X	10K	$\frac{1}{2}$ W	10%	172341000
R20	X	180K	$\frac{1}{2}$ W	10%	172351800
R21	X	4. 7M	$\frac{1}{2}$ W	10%	172364700
R22	Z	22K	$\frac{1}{2}$ W	5%	193542200
R23	Z	330K	$\frac{1}{2}$ W	5%	193553300
R24	X	1500	$\frac{1}{2}$ W	10%	172331500
R25	X	1500	$\frac{1}{2}$ W	10%	172331500
R26	X	10M	$\frac{1}{2}$ W	10%	172371000
R28	Z	68K	1W	5%	193446800
R29	X	1. 5M	$\frac{1}{2}$ W	10%	172361500
R30	X	10K	$\frac{1}{2}$ W	10%	172341000
R2					
R31	X	680	$\frac{1}{2}$ W	10%	172326800
R32	X	10K	$\frac{1}{2}$ W	10%	172341000
R33	X	1. 5M	$\frac{1}{2}$ W	10%	172361500
R34	X	10K	$\frac{1}{2}$ W	10%	172341000
R35	X	6800	$\frac{1}{2}$ W	10%	172336800
R36	Z	62K	$\frac{1}{2}$ W	1%	195446200
R37	Z	120K	$\frac{1}{2}$ W	1%	195446200
R38	X	1500	$\frac{1}{2}$ W	10%	172331500
R39	X	6800	$\frac{1}{2}$ W	10%	172336800
R40	X	10K	$\frac{1}{2}$ W	10%	172341000

Cct. Ref.	General Description				Solartron Part No.
R41	Z	27K	$\frac{1}{2}$ W	1%	195442700
R42	Z	39K	$\frac{1}{2}$ W	1%	195443900
R43	Z	1800	$\frac{1}{2}$ W	1%	195431800
R44	X	56K	$\frac{1}{2}$ W	10%	172345600
R45	Z	1000	$\frac{1}{2}$ W	1%	195431000
R46	X	33K	$\frac{1}{2}$ W	10%	172343300
R47	Z	6800	$\frac{1}{2}$ W	5%	193536800
R48	X	2200	$\frac{1}{2}$ W	10%	172332200
R49	X	39K	$\frac{1}{2}$ W	10%	172343900
R50	Z	1000	$\frac{1}{2}$ W	1%	195431000
R51	X	15	$\frac{1}{2}$ W	10%	172311500
R52	X	10K	$\frac{1}{2}$ W	10%	172341000
R53	X	10K	$\frac{1}{2}$ W	10%	172341000
R54	X	330	$\frac{1}{2}$ W	10%	172323000
R55	X	1000	$\frac{1}{2}$ W	10%	172331000
R56	X	10K	$\frac{1}{2}$ W	10%	172341000
R57	X	10K	$\frac{1}{2}$ W	10%	172341000
R58	Z	3900	$\frac{1}{2}$ W	1%	195433900
R59	X	22K	$\frac{1}{2}$ W	10%	172342200
R60	Z	3300	$\frac{1}{2}$ W	1%	195433300
R61	Z	620	$\frac{1}{2}$ W	1%	195426200
R62	Z	3900	$\frac{1}{2}$ W	1%	195433900
R63	X	4700	$\frac{1}{2}$ W	10%	172334700
R64	X	1000	$\frac{1}{2}$ W	10%	172331000
R65	X	6800	$\frac{1}{2}$ W	10%	172326800
R66	Z	3300	$\frac{1}{2}$ W	1%	195433300
R67	Z	1800	$\frac{1}{2}$ W	1%	195431800
R68	X	33K	$\frac{1}{2}$ W	10%	172343300
R69	X	10K	$\frac{1}{2}$ W	10%	172341000
R70	X	4700	$\frac{1}{2}$ W	10%	172334700
R71	X	100	$\frac{1}{2}$ W	10%	172321000
R72	X	15K	$\frac{1}{2}$ W	10%	172341500
R73	X	47	$\frac{1}{2}$ W	10%	172314700
R74	Z	3300	$\frac{1}{2}$ W	1%	195433300
R75	X	1500	$\frac{1}{2}$ W	10%	172331500
R76	Z	3300	$\frac{1}{2}$ W	1%	195433300
R77	Z	1800	$\frac{1}{2}$ W	1%	195431800
R78	X	68K	$\frac{1}{2}$ W	10%	172346800
R79	X	10K	$\frac{1}{2}$ W	10%	172341000
R80	X	10K	$\frac{1}{2}$ W	10%	172341000
R81	X	10K	$\frac{1}{2}$ W	10%	172341000
R82	X	10K	$\frac{1}{2}$ W	10%	172341000
R83	V	4. 7	$\frac{1}{2}$ W	+0. 5Ω	160100122
R84	Z	100K	$\frac{1}{2}$ W	5%	193451000
R85	X	1000	$\frac{1}{2}$ W	10%	172331000
R86	X	1000	$\frac{1}{2}$ W	10%	172331000
R87	X	10K	$\frac{1}{2}$ W	10%	172341000
R88	X	4700	$\frac{1}{2}$ W	10%	172334700
R89	X	3300	$\frac{1}{2}$ W	10%	172333300
R90	V	9. 1M	1W	0. 5%	B16200085
R91	X	12K	$\frac{1}{2}$ W	10%	172341200
R92	V	900K	$\frac{1}{4}$ W	0. 25%	160400369
R93	Z	2700	$\frac{1}{2}$ W	5%	193532700
R94	Z	220K	$\frac{1}{2}$ W	5%	193552200
R95	Z	33K	$\frac{1}{2}$ W	5%	193543300
R96	Z	150K	$\frac{1}{2}$ W	5%	193551500
R97	Z	3900	$\frac{1}{2}$ W	1%	195433900

Cct. Ref.	General Description					Solartron Part No.	Cct. Ref.	General Description			Solartron Part No.
R98	X	1200	$\frac{1}{2}W$	10%		172331200	MR18	SZD6.8			300522540
R99	Z	1800	$\frac{1}{2}W$	1%		195431800	MR19	SD1			300520070
R100	X	100	$\frac{1}{2}W$	10%		172321000	MR20	SZD6.8			300522540
R101	X	1200	$\frac{1}{2}W$	10%		172321200	MR21				
R102	Z	6800	1W	1%		197536800	to	1N3595	Fairchild		300523590
R103	X	100K	$\frac{1}{2}W$	10%		172351000	MR23				
R104	X	10K	$\frac{1}{2}W$	10%		172341000	MR24	SD1			300520070
R105	X	10M	$\frac{1}{2}W$	10%		172371000	MR25	OA202	Mullard		300521040
							MR26				
RV1	W	20K	$\frac{1}{2}W$	10%		121241000	to	SD1	Solartron		300520070
							MR28				
C1	Ce. T	680p	500V	10%		208400097	MR29	SZD6.8			300522540
C2	Ce. T	680p	500V	10%		208400097					
C3	Ce. D	0.1	3V	-0 +100%		208450076	VT1	D535	Texas		300551620
C4	Pe. T	540p	125V	2.5%		210125400	VT2	D535	Texas		300551620
C5	MPo	1.0	63V	10%		225160000	VT3	A1778/2	Fairchild		300551430
C6	Ce. T	1000p	500V	20%		208400048	VT4	ACY21	Mullard		300550490
				-25			VT5	A1778/2	Fairchild		300551430
C7	Ce. D	0.1	18V	+50%		208450052	VT6	ACY21	Mullard		300550490
C8	Ce. T	220p	500V	10%		208400046	VT7	SM6526	Motorola		300552990
C9	Ce. D	0.1	18V	-25 +50%		208450052	VT8	ACY21	Mullard		300550490
C10	MPo	1.0	63V	10%		225161000	VT9	ACY21	Mullard		300550490
C11	Ce. T	680p	500V	10%		208400097	VT10	D535	Texas		300551620
C12	MPo	0.068	250V	10%		225746800	VT11	SM6526	Motorola		300552990
C13	Ce. T	1500p	500V	10%		208400056	VT12	A1778/2	Fairchild		300551430
C14	MPo	0.01	400V	10%		226041000	VT13	A1778/2	Fairchild		300551430
				-20			VT14	ACY21	Mullard		300550490
C15	El	250	15V	+50%		208600149	VT15	D535	Texas		300551620
C16	Ce. T	2200p	500V	20%		208400083	VT16	2N2484	Fairchild		300552860
C17	MPo	0.1	100V	10%		225451000	VT17	2N2484	Fairchild		300552860
C18	Pe	0.47	63V	1%		208100127	VT18	A1778/2	Fairchild		300551430
C19	Pe	0.47	63V	1%		208100127	VT19	SM6526	Motorola		300552990
C20	Po	0.068	250V	5%		208200116	VT20	D535	Texas		300551620
C20	Po						VT21	SM6526	Motorola		300552990
C21	Ce. T	2200p	500V	20%		208400083	VT22	D535	Texas		300551620
C22	Po	.047	250V	5%		208200120	VT23	A1778/2	Fairchild		300551430
C23	Ce. T	2200p	500V	20%		208400083	VT24	40327	R. C. A.		300552890
C24	MPo	0.1	250V	10%		225751000	VT25	A1778/1	Fairchild		300551430
C26	MPo	.01	400V	10%		226041000	VT26	A1778/1	Fairchild		300551430
							VT27	A1778/1	Fairchild		300551430
							VT28	D535	Texas		300551620
MR1							V1	M8136	Mullard		300033091
to	SD1	Solartron				300520070	V2	83A1	Mullard		300011110
MR5											
MR6	HG5001	Hughes				300523650	XL1	4435	STC		A16200011
MR7	HG5001	Hughes				300523650					
MR8	OA200	Mullard				300520720	T1		Solartron		B16200012
MR9	OA200	Mullard				300520720					
MR10	SZD6.8					300522540					
MR11	OA200	Mullard				300520720					
MR12											
to	SD1	Solartron				300520070					
MR14											
MR15	HG5001	Hughes				300523650					
MR16	SD1	Solartron				300520070					
MR17	SD1	Solartron				300520070					

Component Parts List for Printed Circuit Board No.1 (Cct. Ref. 16199101)					
Cct. Ref.	General Description				Solartron Part No.
R1	X	7.5M	$\frac{1}{2}W$	10%	172367500
R2	X	15M	$\frac{1}{2}W$	10%	172371500
R3	X	4.7M	$\frac{1}{2}W$	10%	172364700
R4	X	100K	$\frac{1}{2}W$	10%	172351000
R5	X	10	$\frac{1}{2}W$	10%	172311000
R6	X	12K	$\frac{1}{2}W$	10%	172341200
R7	X	330K	$\frac{1}{2}W$	10%	172353300
R8	X	27K	$\frac{1}{2}W$	10%	172342700
R9	X	2200	$\frac{1}{2}W$	10%	172332200
R10	X	100K	$\frac{1}{2}W$	10%	172351000
R11	V	39K	$\frac{1}{4}W$	0.5%	160400298
R12	V	22K	$\frac{1}{4}W$	0.25%	160400297
R13	V	22K	$\frac{1}{4}W$	0.25%	160400297
R14	Z	100K	$\frac{1}{2}W$	1%	195451000
R15	Z	100K	$\frac{1}{2}W$	1%	195451000
R16	Z	22K	1W	1%	197542200
RV1	WW	2000	1W	10%	110075060
C1	Po	0.047	630V	20%	220444700
C2	Po	0.047	250V	20%	225844700
C3	Ce. T	180p	500V	20%	208400039
C4	Ce. T	100p	500V	10%	208400044
C5	E1	15	20V	20%	208700078
C6	Po	2.2	63V	20%	225262200
C7	Po	1.0	63V	20%	225261000
C8	Po	1.0	63V	20%	225261000
MR1	IN914				300522160
MR2	OA200		Mullard	300520720	
MR3	OA200		Mullard	300522160	
MR4	IN914				300522160
MR5	IN914				300522160
MR6	IN3595		Fairchild	300523590	
MR7	IN3595		Fairchild	300523590	
VT1	2N2484		Fairchild	300552860	
VT2	SM6526				300552590
VT3	SM6526				300552590
VT4	2N2484		Fairchild	300552860	

Component Parts List for Printed Circuit Board No.2					
Cct. Ref.	General Description				Solartron Part No.
R1	Z	100K	1W	5%	193451000
R2	V	89K	$\frac{1}{4}W$	0.2%	160400364
R3	V	9900	$\frac{1}{4}W$	0.2%	160400363
R4	V	1090	$\frac{1}{4}W$	0.2%	160400362

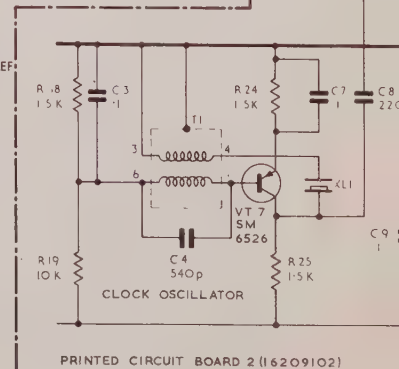
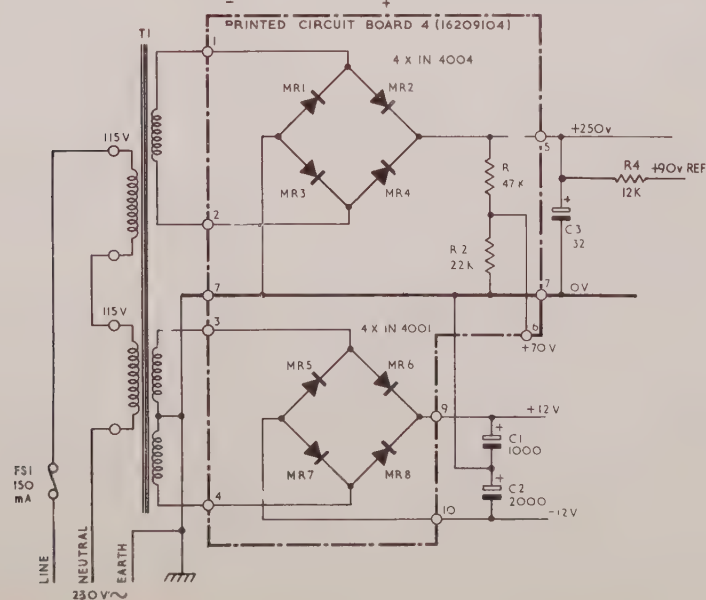
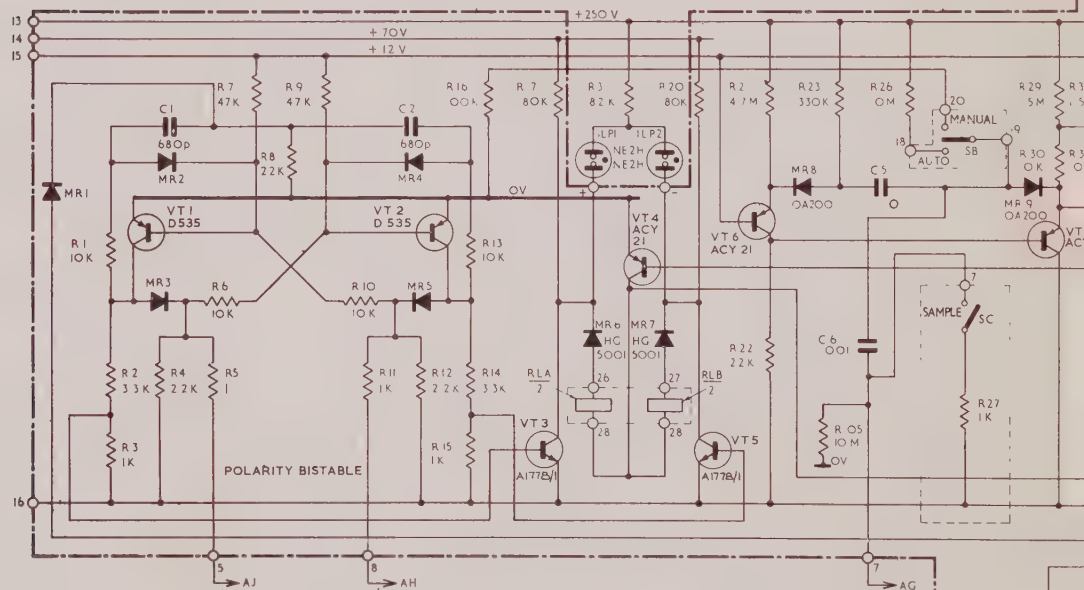
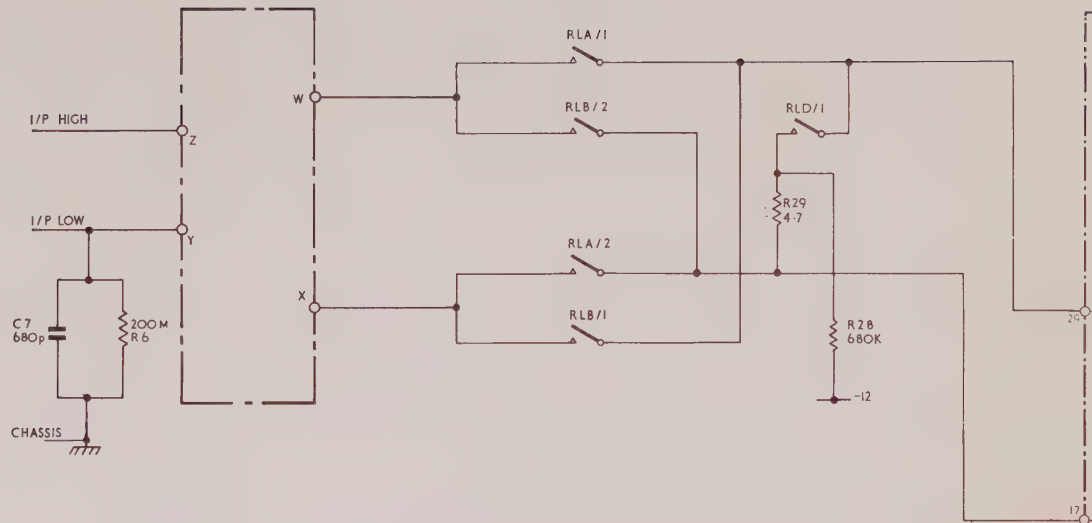
Cct. Ref.	General Description				Solartron Part No.
R5	X	100K	$\frac{1}{2}W$	10%	172351000
R6	Z	47K	$\frac{1}{2}W$	5%	193544700
R8	Z	47K	$\frac{1}{2}W$	5%	193544700
RV1	WW	20K	1W	5%	12124200
RV2	WW	2000	1W	10%	110075060
RV3	WW	200	1W	10%	110075030
RV4	X	20	$\frac{1}{2}W$	30%	110025100
C2					
to	2/23p				290060020
C4					
C5	Po	0.22	100V	5%	208200123
C7	Po	0.15	100V	5%	208200132
V1	Lamp Neon 29L				300720170

Component Parts List for Printed Circuit Board No.4					
Cct. Ref.	General Description				Solartron Part No.
R1	Z	47K	$\frac{1}{2}W$	1%	197544700
R2	X	33K	$\frac{1}{2}W$	10%	172343300
MR1					
to	1N4004 Motorola				300522070
MR4					
MR5					
to	1N4001 Motorola				300522060
MR8					

Component Parts List for Main Assembly					
Cct. Ref.	General Description				Solartron Part No.
R1	V	890K	2W	0.25%	160400354
R2	V	9.9M	2W	0.5%	162000103
R3	X	82K	$\frac{1}{2}W$	10%	172348200
R4	Y	12K	3W	1%	173641200
R5	X	120K	$\frac{1}{2}W$	10%	172351200
R6	X	200M	$\frac{1}{2}W$	20%	160100026
R11	X	1000	$\frac{1}{2}W$	10%	172331000
R12	X	22K	$\frac{1}{2}W$	10%	172342200
R27	X	1000	$\frac{1}{2}W$	10%	172331000
R28	X	680K	$\frac{1}{2}W$	10%	172356800
R29	X	4.7	$\frac{1}{2}W$	+	5Ω 160100122
R30	X	680	$\frac{1}{4}W$	10%	172026800

Cct. Ref.	General Description				Solartron Part No.
RV1	WW	400	$\frac{1}{4}$ W	10%	110075130
RV2	WW	2000	1W	5%	121932000
C1	E1	1000	15V	-20 +100%	208600177
C2	E1	2000	15V	-20 +100%	208600178
C3	E1	32	350V	-20 +100%	262373201
C4	Po	0.47	100V	5%	208200130
C5	Po	22p	500V	0.5p	208100112
C6	Po	15p	500V	0.5p	208100098
C7	Po	680p	500V	10%	210526800
C8	Ce. D	1000p	500V	-20% +80%	241031000
C9	Ce. T	2200p	500V	20%	208400083
MR1		SD1	Solartron		300520070
MR2		SD1	Solartron		300520070
BY1		Standard Cell			310010060
FS1		Fuse Link	150mA Slow Blow		360105040
T1		Mains Transformer			B16200001
RLA		Relay & Coil Assy			AD16200093
RLB		Relay & Coil Assy			AD16200093
RLC		Relay & Coil Assy			AD16200094
RLD		Relay & Coil Assy			AD16200094
RLE		Relay & Coil Assy			AD16200093
RLF		Relay & Coil Assy			AD16200093
SA		Switch Wafer Front			B16190003
SB		Switch Slider			375000450
SC		Switch P. B.			377000130
ILP1 to ILP5 ILP6		NE2H	Lamp Neon		300720220
		23L	Lamp Neon		300720240

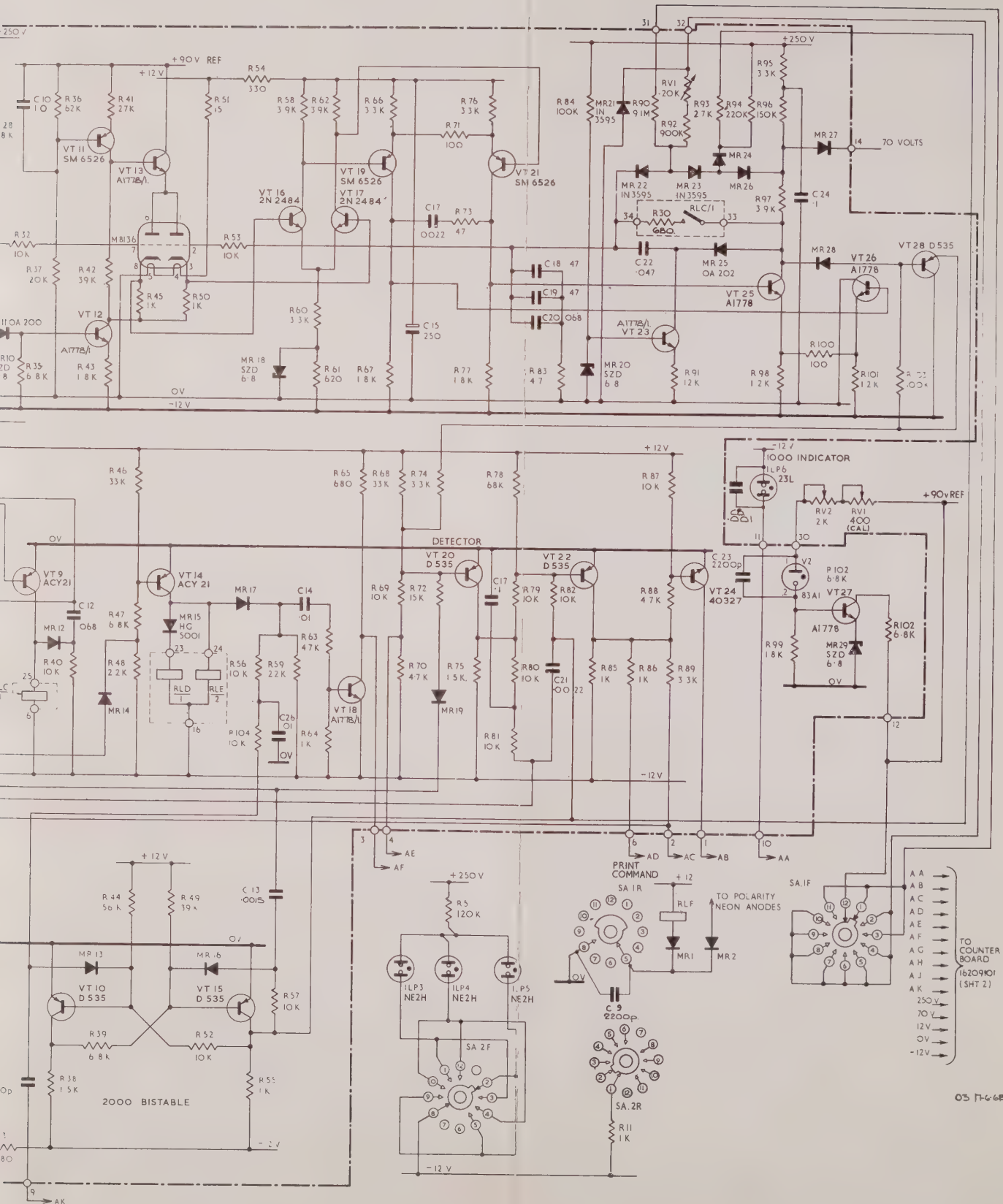
Batteries: Three Mallory Mercury Cells type TR146X



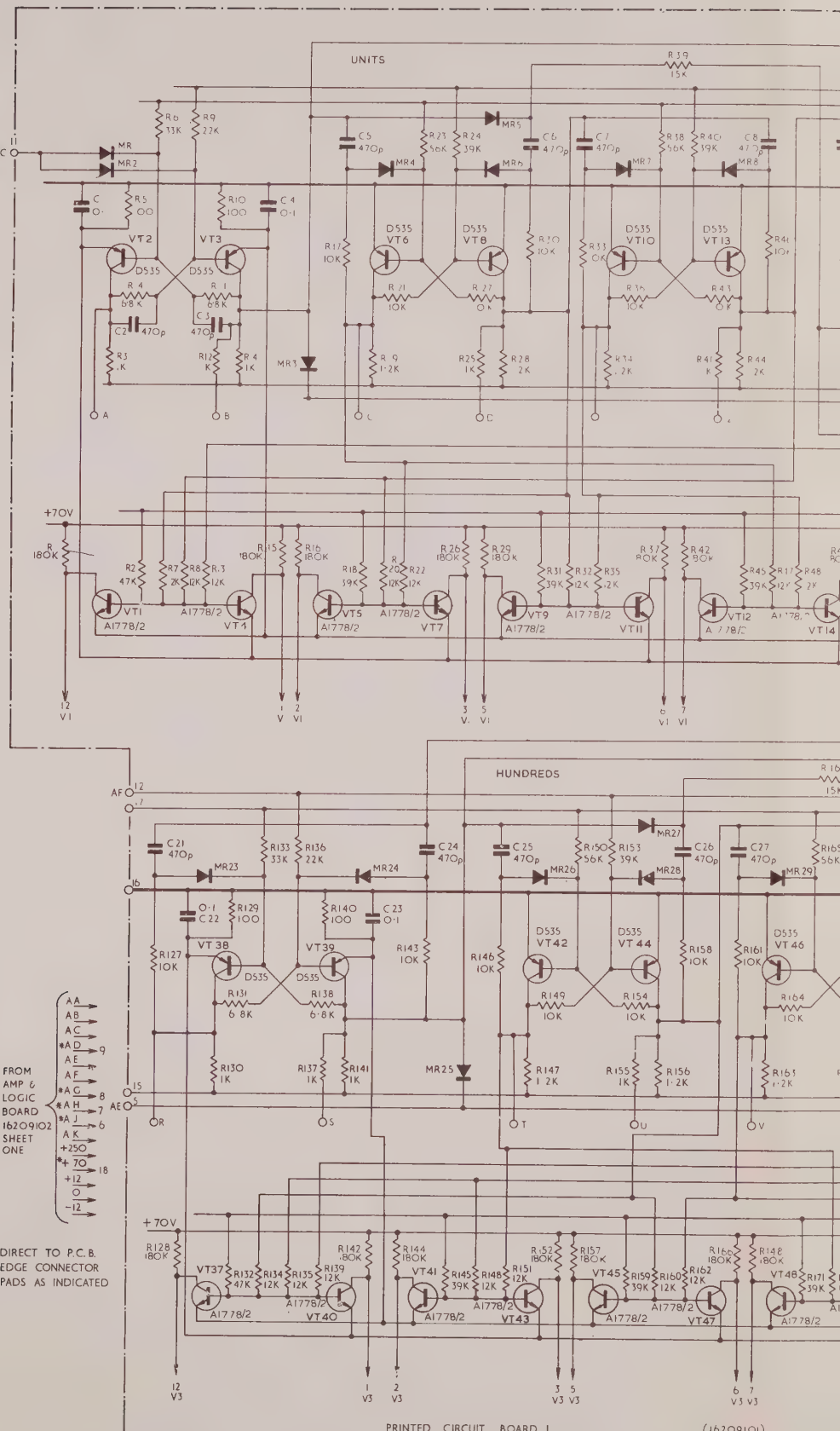
NOTE

1. DIODES SDI UNLESS OTHERWISE SPECIFIED

2. SWITCH WAFERS SHOWN IN COUNTER-CLOCKWISE POSITION



*rated
clock pulses*

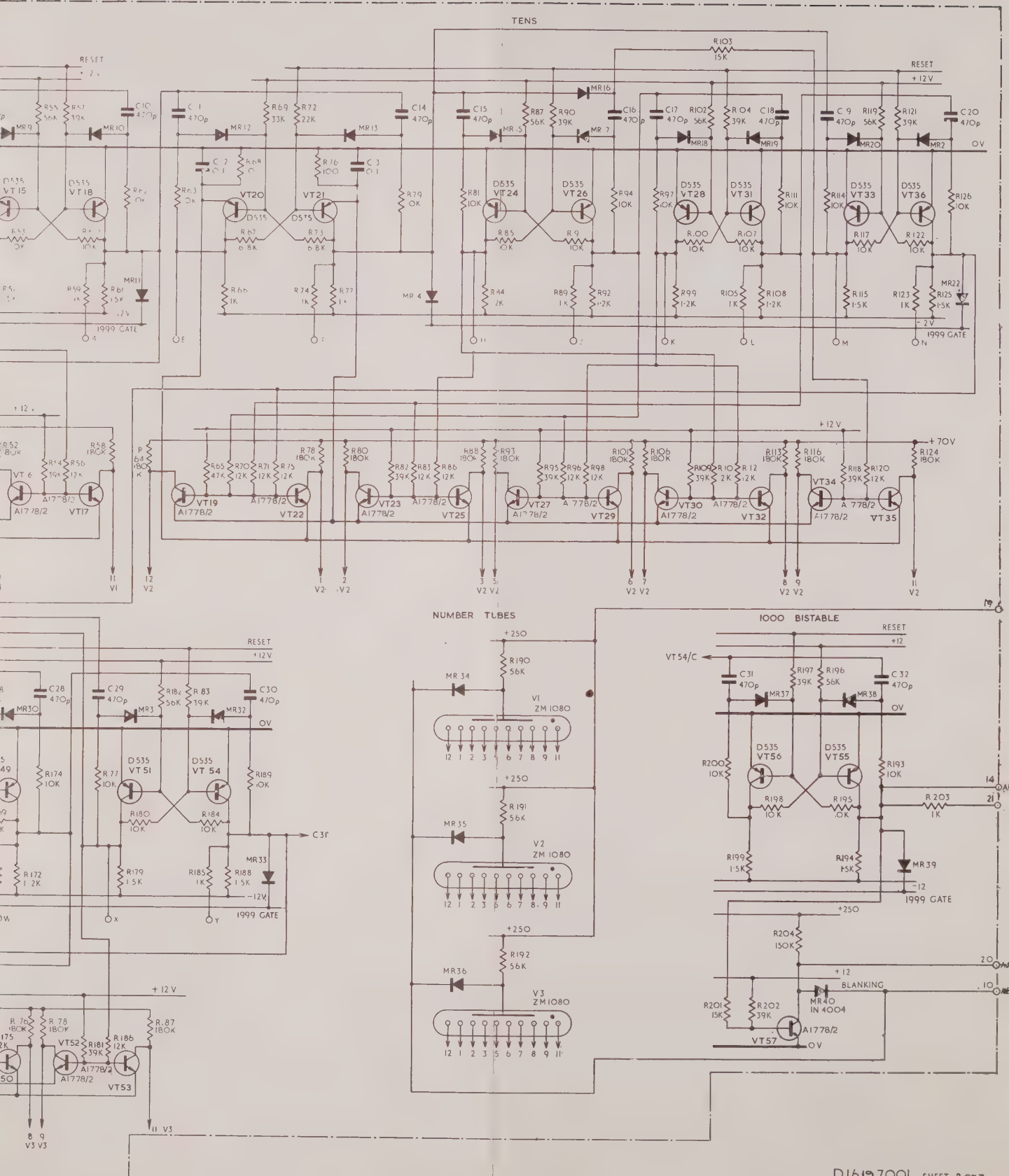


FROM
AMP 6
LOGIC
BOARD
16209102
SHEET ONE

AA
AB
AC
AD
AE
AF
AG
AH
AJ
AK
+250
+70
+12
-12

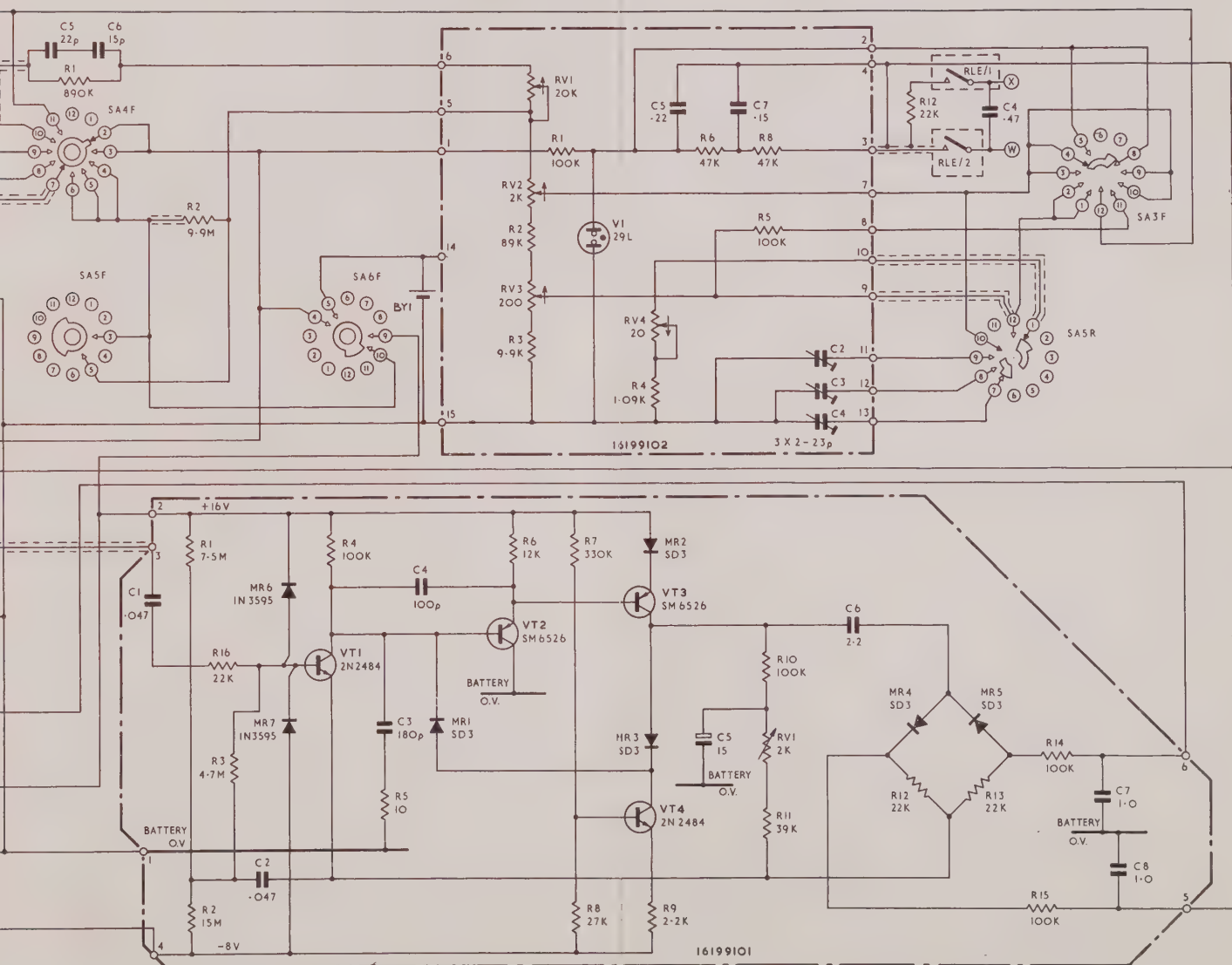
• DIRECT TO P.C.B.
EDGE CONNECTOR
PADS AS INDICATED

NOTE: 1. OUTPUTS FROM THE P.C.B. APPEAR AT A 42 WAY EDGE CONNECTOR AND ARE IDENTIFIED WITH NUMBER AND LETTER SYMBOLS TO CONFORM WITH THE DESIGNATIONS ON 42 WAY FAN-OUT CONNECTOR EX 1866.
2. ALL DIODES SDI UNLESS OTHERWISE STATED





ALL RELAYS MOUNTED ON
REAR OF SCREEN BOX.



ADDENDUM 1 RANGE OUTPUT MODIFICATION

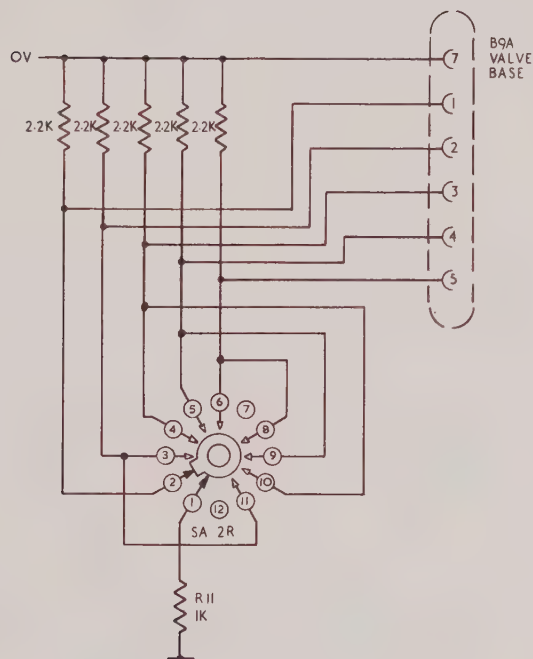


Diagram 1

This modification may be carried out if range output information is required to augment the print-out information provided. When completed the modification provides outputs of approximately -8 volts via 1000Ω [R11] on five lines via switchbank SA2R of the range selector.

Parts List

- 5 - resistor 2200Ω $\frac{1}{2}$ W 10%
- 1 - valve base B9A
- 2 - screw, cheesehead 6BA x 3/8"
- 2 - whole nut 6BA
- 2 - star washer 6BA
- 1 - solder tag 6BA
- 5 - wire, 7/0076 x 17" length [assorted colours]
18 S.W.G. tinned copper wire - as required
lacing cord, nylon - as required.

Assembly Instructions

The completed modification will consist of five resistors mounted on a B9A valve base fitted at the rear panel of the instrument. The five connecting wires run parallel to the existing cableform alongside the power supply sub-chassis and attenuator box to spare contacts 2 to 6 of switch wafer SA2R. Resistor R11 [1K] is already fitted and the fixing hole for the valve base is provided, blanked off with a removable bung. Fig. 4.6 [Section 4] shows location of switch wafer SA2R and the positions of the appropriate contact tags.

The linking wires shown on Diagram 1 coupling the corresponding AC and DC ranges are also fitted, although not shown on the instrument circuit diagram.

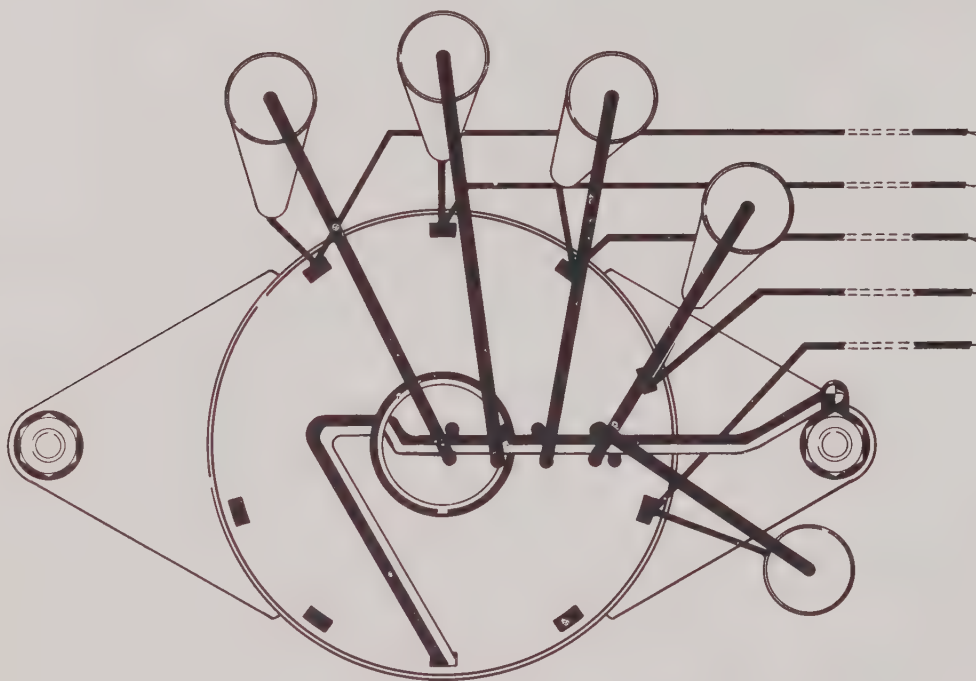


Diagram 2

1. Wire valve base as shown in diagram 2 and take note of the colour coding of the connecting wires to the pins of the valve base.
2. Remove the bung in the rear panel of the instrument and fit the valve base.
3. Arrange the connecting wires into a cableform and lace up. Route to the front of the instrument beside existing cableform.
4. Cut to length, strip and then solder each connecting lead to the appropriate tag of switch wafer SA2R as per Diagram 1.

This completes the modification.

Final Check

Connect the instrument to the mains supply and measure the outputs with a voltmeter at pins 1 - 5 of the valve base.

An output of approximately -8V should appear at each pin with appropriate positioning of the range selector as listed.

D.C. Ranges	Output	A.C. Ranges	Output
200mV	Pin 1	750V	Pin 5
2V	2	200V	4
20V	3	20V	3
200V	4	2V	2
1kV	5	BTY>14V	None
CAL	None		

Affect on Instrument Calibration

Provided that care has been taken not to disturb any preset controls during the modification work the calibration of the instrument should not be affected. It is good practice, however, to carry out the test procedure as described in Section 4 of the manual following any internal work carried out on the instrument.

Decode to BCD

If the output device available requires the range information to be presented in BCD form the following decode matrix may be of use. The output level will be reduced by the forward voltage drop from a maximum of two diodes. The actual value determined by the diode type employed.

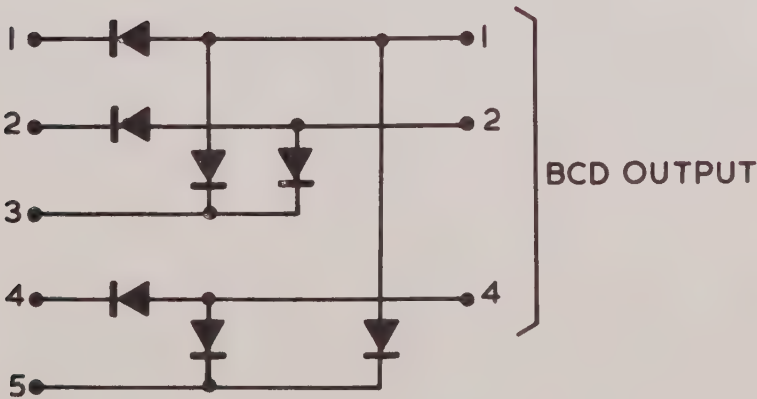


Diagram 3

ADDENDUM 2

SERIES AND COMMON MODE INTERFERENCE

General

The digital voltmeter is a very sensitive instrument capable of measuring with extreme precision. Consequently, interference signals induced into its input leads or originating in the source under measurement will give rise to spurious inputs capable of rendering a reading valueless when very small inputs are applied to the voltmeter.

To overcome such difficulties special techniques are employed in both the design and operation of the voltmeter and their consideration is conveniently carried out by classifying interference in two forms - common mode and series mode.

Series Mode

This is generated in series with the signal source and is sometimes called 'Normal Mode'.

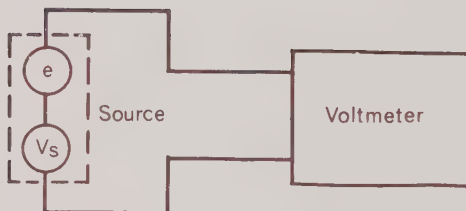


Diagram A

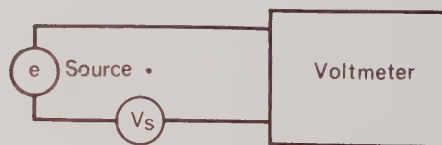


Diagram B

It may arise as part of the source, as shown in diagram A, where the signal to be measured [e] and the interference [V_s] are superimposed upon one another, or as pick-up on the connecting leads, diagram B.

If a DC source is being measured and the interference is also D.C. the unwanted signal must be cancelled by a backing off technique. This facility is not normally built in to digital voltmeters and is rarely required.

The permanently connected filter of LM1619, on DC ranges only, provides greater than 40dB rejection of series mode interference at 50Hz, increasing at 12dB per octave at higher frequencies. Thus with a display of 1 volt, interference at 50Hz will have to be at least 100mV in order to produce flicker in the last [1mV] window. Similarly, at least 10 volts of interference at 400Hz are required for flicker to occur.

Common Mode

This, by definition, is interference common to both input leads of the voltmeter, all input circuitry moving with respect to earth. This interference will not in itself give rise to errors, since the voltmeter will measure the potential difference between its input terminals. However, in most circumstances, the common mode interference will give rise to a series mode signal capable of introducing errors.

In the older type of instrument it was frequently the practice to take signal LO to chassis and thence to mains earth. If the signal source was also earthed, the circuit became that of diagram C.

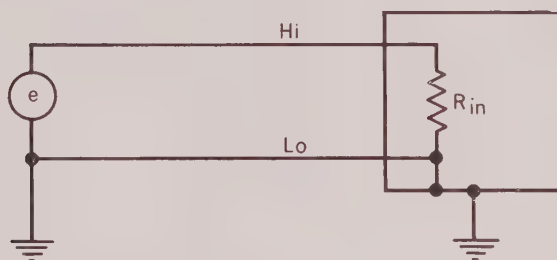


Diagram C.

It is now generally realised that the two earths are not necessarily at the same potential, and in industrial instrumentation there may be a potential of several volts between them. This is developed across the impedance of the LO lead and a current of several amps may flow. Hence, the error will be equal to the potential difference between the two 'earths'.

It is thus very desirable to have fully floating input circuits so that the source may be tied to a potential which is not earth. Diagram D shows a floating input circuit employed to measure a source [e] which is at a common mode potential [V_C]. The common mode current which flows in the LO lead is now limited to a very small value by the leakage resistance to chassis. With LM1619 V_C may be as much as 250V peak or D.C. while the leakage resistance R_L is 200M Ω .

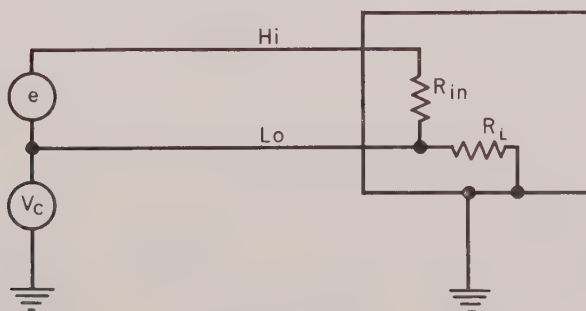


Diagram D

The input circuit of the LM1619 is contained within a screened compartment which may be isolated from earth by the removal of a link between terminals LO and CHASSIS, as shown in diagram E.

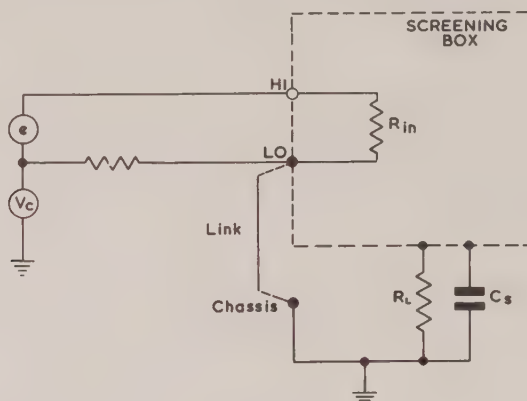


Diagram E

Common Mode Performance

The performance is specified as a ratio and expressed in dB. Rejection on the two basic ranges [200mV and 2V] of the D.C. instrument is greater than 80dB at DC and 50Hz. This means that the error voltage will be >80dB down on the interference voltage [V_c]. Alternatively a 10V peak or D.C. common mode signal will result in an error reading of less than 1mV. The effect of stray capacitance [C_s] shunting the leakage resistance [R_L] for A.C. common mode signals is compensated for by the action of the permanently connected filter on the resultant increased A.C. series mode error signal.

Since common mode signals are common to both input terminals of the voltmeter they are not divided down by the input attenuator and the resultant error voltage will be the same for all ranges. Thus the attenuator appears as a common mode multiplier as shown in table 1.

Range	Attenuation	Common Mode Rejection
200mV DC	0	80dB [10,000:1]
2V DC	0	80dB
20V DC	X100	40dB [100:1]
200V DC	X100	40dB
1kV DC	X1000	20dB [10:1]
2V AC	0	60dB [1000:1]
20V AC	X10	60dB
200V AC	X100	40dB [100:1]
750V AC	X1000	20dB [10:1]

Table 1.

On A.C. ranges since the entire AC/DC converter circuitry is floating, common mode signals will be applied, as before, to the input of the D.C. instrument, the converter appearing as an unbalance resistance in the input leads. In addition, any unbalance existing in the source of the common mode signal will result in a series mode signal capable of producing a DC output from the converter. These effects are most noticeable on the 2V A.C. range and degrade the performance by a factor of 20dB. The resultant rejection is thus 60dB. On the remaining ranges their effects are progressively swamped by the multiplier effect of the attenuator and performance is then directly comparable with that of the D.C. attenuated ranges.

ADDENDUM 3 **RACK MOUNTING**

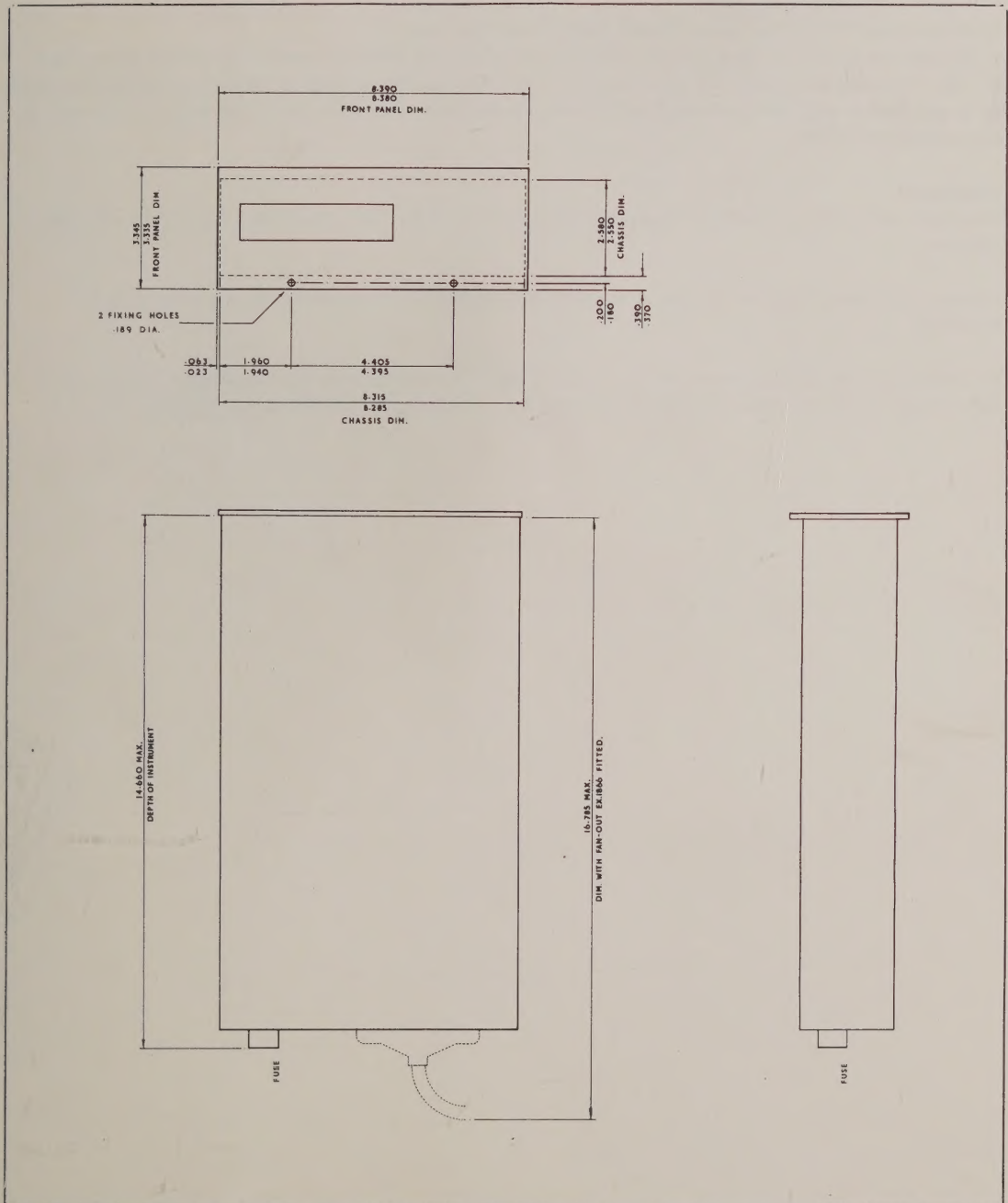


Diagram 1 LM1619 Dimensions for Rack Mounting.

Introduction

The LM1619 conforms to international standard [ISEP] constructional formats allowing for simple installation in 19" racking.

Preparatory

- 1] Remove top and bottom covers.
- 2] Remove two "T" section cover retaining strips from front-panel.
- 3] Remove range selector knob, input terminal link and six 6BA Phillips-headed screws from front-panel.
- 4] The melamine facia may now be removed to reveal the two fixing holes at the bottom of the front-panel.
- 5] Mark-through and drill two corresponding holes in the melamine facia. [Ready drilled facia-panels can be supplied on request].

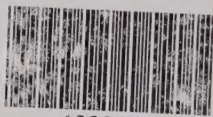
Installation

Diagram 1 shows all the relevant dimensions and tolerances of the complete instrument chassis with panels removed.

Where a particularly rigid installation is required ISEP standard rack-mounting kits are commercially available.

For permanent installations, where the rack is unlikely to be moved, it should be sufficient in view of the light weight of the instrument for it to be mounted with two fixing screws between two parallel ISEP bars.

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